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ABSTRACT

OF THE

PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSIONS 11 TO 15,

1869—74.

(The Authors having revised their own Papers, are alone responsible for the facts and opinions expressed in them.)

VOL. 2.

LIVERPOOL:
COURIER PRINTING WORKS, VICTORIA STREET.
1874.

54

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ABSTRACT OF THE PROCEEDINGS
OF THE
LIVERPOOL GEOLOGICAL SOCIETY.

TABLE OF CONTENTS,
SESSIONS XI TO XV, INCLUSIVE,
CONSTITUTING VOL. II.

SESSION XI. 1869–70.

PRESIDENT'S ANNUAL ADDRESS.
By G. H. Morton, F.G.S., F.R.G.S.I.

Geological Observations in the Neighbourhood of Exeter.
By C. Ricketts, F.G.S.

The Formation of Metalliferous Veins.
By A. Morgan.

The Mersey and the Dee—their former Channels and Changes of Level.
By R. Bostock.

On Deep Sea Dredgings in the Atlantic.
By Rev. S. Cooke, M.A.

The Sections of Strata exposed on the Huyton and St. Helens Branch Railway.
By C. Ricketts, M.D., F.G.S.

SESSION XII. 1870–71.

PRESIDENT'S ANNUAL ADDRESS.

By G. H. Morton, F.G.S., F.R.G.S.I.

Remarks on the Lower Silurian Rocks in the Neighbourhood of Llanfyllin, and on the Contortions of the Strata.

By C. Ricketts, M.D., F.G.S.

The Theory of Colonies.

By R. A. Eskrigge, F.G.S.

Observations on Metalliferous Deposits.

By A. Morgan.

Alternations of Sea and Land, Astronomically Considered.

By R. Bostock.

Effect Produced by Red Sandstone upon Salt Water.

By I. Roberts, F.G.S.

Sections of the Boulder-Clay at the Gas Works, Linacre, near Liverpool.

By I. Roberts, F.G.S.

On some Specimens, supposed to be Fossils of a Plant named Pycnophyllum (Brongniart and Schimper); Flabellaria (Sternberg); Nœggerathia (Nonnul); in the Ravenhead Collection of Fossils, Free Public Museum, Liverpool.

By Rev. H. H. Higgins, M.A.

SESSION XIII. 1871–72.

PRESIDENT'S ANNUAL ADDRESS.

By C. Ricketts, M.D., F.G.S.

The Geology and Physics of the Post-Glacial Period, as shewn in the Deposits and Organic Remains in Lancashire and Cheshire.

By T. M. Reade, C.E., F.G.S.

Remarks on the Volcanic Rocks near Edinburgh.

By C. Ricketts, M.D., F.G.S.

Minerals that occur in the Neighbourhood of Liverpool, with the Localities, &c.

By G. H. Morton, F.G.S.

Shells Found in the Glacial Deposits around Liverpool, with the Localities, &c.

By G. H. Morton, F.G.S.

On some Fossil Ferns in the Ravenhead Collection, Free Public Museum, Liverpool.

By Rev. H. H. Higgins, M.A.

On some Fossil Ferns in the Ravenhead Collection.

By F. P. Marrat.

SESSION XIV. 1872–73.

PRESIDENT'S ANNUAL ADDRESS.

By C. Ricketts, M.D., F.G.S.

Glacial Striæ at Miller's Bridge, Bootle, near Liverpool.

By T. M. Reade, C.E., F.G.S.

Section of Strata above the Boulder-Clay at Whitechapel, Liverpool.

By I. Roberts, F.G.S.

Calamites and their Alliances.

By F. P. Marrat.

The Graptolites of the Arenig Rocks of St. David's, South Wales.

By J. Hopkinson, F.G.S., F.R.M.S.

The Buried Valley of the Mersey.

By T. M. Reade, C.E., F.G.S.

SESSION XV. 1873–74.

PRESIDENT'S ANNUAL ADDRESS.

By I. Roberts, F.G.S.

List of Works relating to the Carboniferous Limestone and Millstone Grit of North Wales.

By G. H. Morton, F.G.S.

Notes on the Phenomena of Glacial Action in Norway.

By J. A. Picton, F.S.A.

On some Graptolites from the Upper Arenig Rock of Ramsey Island, St. David's.

By J. Hopkinson, F.G.S., F.R.M.S.

Tidal Action as a Geological Cause.

By T. M. Reade, C.E., F.G.S.

The Metamorphic Rocks of the Malvern Range and the Strata derived from them.

By C. Ricketts, M.D., F.G.S.

ABSTRACT

OF THE

PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION THE ELEVENTH,

1869—70.

LIVERPOOL:
COURIER STEAM PRINTING WORKS, 44, CABLE STREET.
1870.

OFFICERS, 1869—70.

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ABSTRACT OF THE PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION ELEVENTH.

At an Extraordinary Meeting of the Society held 12th October, 1869, the Rules as revised and altered by the Council, were approved and ordered to be printed as amended.

OCTOBER 12TH, 1869.

Anniversary Address by the President, George H. Morton, F.G.S., F.R.G.S.I.

Gentlemen,

The swift passage of the months has again brought us to the opening of another Session, and we may now commemorate the end of the first decade in the years of our Society's existence.

When the first meeting was held, in December, 1859, it was neither intended nor expected that the Society would become one of the prominent institutions of Liverpool for the cultivation of Physical Science. The experience of a few months, however, was sufficient to prove the desirability of holding the meetings in a public building, instead of at the residence of one of the members. As the years passed on the Society became vigorous, the number of members increased; while the general progress that has been made is apparent in the annual "Abstract of Proceedings" which has been regularly circulated among the members. There is a wide difference between the feeble effort of the first Session and the valuable volume that has just been printed.

The organisation of a Geological Society in Liverpool was attended with some difficulty. It was said that such a Society, "more especially in a district of country which offers so little to be worked out that is not already known, and moreover in a town purely commercial, where with few exceptions the people are too much engrossed with other pursuits, and care little or nothing for science in any shape, would be too contracted to permit of its existence beyond a very limited period."* This prophetic warning was disregarded, for the Society was established, and Mr. Henry Duckworth, F.G.S., F.L.S., read the Inauguration Address at the first meeting.

As may be naturally expected, the Society has lost some of its first members. Many whose names are contained in our early lists have, from leaving the town and various other causes, ceased to belong to our Society. Some have been removed by death, including Mr. Thomas Urquhart, who attended the first meeting, was a member of our Council, and took great interest in our proceedings. The greatest loss sustained by the Society was the untimely decease of Mr. William S. Horton, F.G.S., at the early age of 25 years. Several of his communications are inserted in our "Abstract of Proceedings," and there are others in "The Geologist" Magazine. Many of us remember his presence among us, while the few who, like myself, enjoyed his company in the country, hammering over the hills in the pursuit of our noble science, can never forget him. More recently we have lost Mr. Edwin Stirling, who was a contributor of geological information at our meetings. During the recess we have had to regret the decease of Mr. William Burke, who, though he did not take any active part in the business of the Society, was a frequent attendant and known to most of us.

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* Letter to the Hon. Sec., December, 1859.

I have also to record the death of one of our Honorary Members, the late Professor J. Beete Jukes, M.A., F.R.S., Director of Her Majesty's Geological Survey in Ireland, and Professor of Geology to the Royal College of Science. He was born near Birmingham in 1811, and was in his 58th year when he died. I need not make any comment on this great loss to geological science.

In addition to the introduction of many new laws for the regulation of our Society, it has become a part of your President's duty to open each Session with an Address, though the subject, or rather the general bearing of it, seems to have been left to his discretion.

The progress of geological science during the previous year is always a convenient subject for such an Address, though it is apt to be a mere repetition of what is already familiar to every reader of our current scientific literature, in which every new fact and theory is regularly presented to us either in a monthly or quarterly form.

A review of the proceedings of a Society during the previous Session also provides material for an Anniversary Address.

It is not unusual for the President of a Scientific Society to devote his Address to the consideration of some subject to which he has given particular attention, and as it seems that I shall be most likely to interest you by adopting such a course, I have decided on confining my observations to the progress of geological research in this district.

There can be no doubt that our geological observations should begin at home, where we have sufficient time and opportunity to study phenomena, which could not be satisfactorily done by a casual observer. When we attempt to investigate a distant locality we do so under great disadvantages, and cannot compete with geologists who reside near the place. It is for these reasons that in the published proceedings of provincial Geological and Natural History Societies the local contributions are almost always the most valuable; indeed, as a general rule, the others are of little or no value.

Similar observations apply to geological collections in public museums, for the most valuable are those which illustrate the geology of the district where they are situated, such as those at Bristol, Cambridge, Oxford, Manchester, Norwich, and York. Those of London, Edinburgh, and Dublin are national museums of a more comprehensive character. In Liverpool, although we have two public museums, we have no geological collection commensurate with the importance of the town. The fossils in the Royal Institution are absolutely useless in their present condition. The geological collection in the Free Public Museum is a very small one, if we exclude the somewhat incongruous accumulation of bulky specimens which occupy space sufficient to accommodate thousands of smaller ones forming the links of a connected series. It cannot be too generally known that there is no geological collection in Liverpool to which a student can go and study palæontology with any satisfaction. We have a College and a School of Science in which geology is taught, and we should have a collection of fossils in either one or both of our museums, properly named and sufficiently comprehensive for educational purposes. It seems desirable that the collections in our two museums should be united, for if the fossils in the Royal Institution were added to those in the Free Public Museum, we should at once have an ample nucleus from which, with gradual additions, we might soon have a valuable collection. From the position of Liverpool—distant from any very fossiliferous formation—it is undesirable to give undue prominence to any particular strata, but rather to aim at forming a collection of an educational character, which would be most in accordance with the intention of the Act of Parliament, authorising the support of local museums by means of a rate levied on the inhabitants of large towns.

The geology of the country around Liverpool recognises three distinct stratified groups, viz.:—The Carboniferous strata, the Triassic strata, and those superficial Post-Pliocene and Recent deposits, which cover the older rocks and sometimes present a stratified condition.

In the absence of any satisfactory geographical boundary, we are almost compelled to adopt a geological area, and to consider the Mountain Limestone of Flintshire as our foundation rock. That formation occurs within 15 miles from the Liverpool Exchange, and by including it in our local area we have the whole of the Carboniferous Group, which is fully 6,500 feet thick. The overlying Triassic Group is 1,700 feet thick, so that the base of the Mountain Limestone is probably very nearly 8,500 feet beneath our feet.*

The area occupied by each of the sub-divisions of the Carboniferous and Triassic formations was practically known, long before the Geological Survey of the district, by those persons whose pecuniary interest it was to investigate the subject. The country occupied by the Carboniferous Limestone in Flintshire is indicated by numerous quarries, some of which were worked centuries ago. The value of the stone as a building material and for lime burning caused the extent of the limestone district to be accurately known, while the metallic lodes so characteristic of the formation have been referred to by very early writers. The lead mines of Flintshire were probably worked during the Roman occupation of Britain.* The extent of the Coal-measures in that county and in the neighbourhood of Liverpool has been long known.

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* "Geology of Liverpool," Plate 2, and "Proceedings, Liverpool Geological Society," 1861-2.

In Great Britain and other countries in Europe, from the most remote antiquity, even in Pre-Historic times,† there seem to have been collectors of curious natural objects, including fossils. According to Dr. Leigh, there must have been many geological collections in this part of England in his time. A few short sentences from his interesting work on the "Natural History of Lancashire, Cheshire, and the Peak of Derbyshire," published at Oxford in the year 1700, give an idea of the opinions which then prevailed in Lancashire regarding the origin of organic remains.

> "Amidst all the mazes and recesses of nature, none are "more common or more amazing than these following phenomena: "Near Chippin, in Lancashire, twenty fathom in limestone rock, "I have seen cockles, muscles, and the Pectinites, all of a perfect "flinty substance. In High-Furness in the same county I have "observ'd, as to their outward appearances, the bones and fins of "fishes, and sometimes bones of a gigantic magnitude, and those "of a sparry substance, which may be reduc'd to the Fluor "Alabastrites; I have likewise seen the Glossopetræ or Crow-"bills, and those invest'd with a hard flinty film, the matter "contain'd therein being a black hard stone. Upon these "phenomena it is that Dr. Woodward supposes them to be the "Exuviæ of those creatures at the Deluge, and deposit'd in those "rocks by specific gravitation," &c.‡

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* Thomas Wright, F.S.A., *Intellectual Observer*, vol. 1, 1862.

† Dupont, *Quartarly Journal Geological Society*, 1866.

‡ Dr. Leigh, p. 114.

After describing several kinds of testaceous petrifactions, he says:—

"We therefore come in the next place to lay down some "arguments why those bodies could not be the Exuviæ of animals "at the deluge: for had these been the Exuviæ of fowls, fishes, "and other creatures, how is it possible but that other shells, and "beaks of other fowls, as well as of these, might sometime or "other have been discover'd in these rocks; but since no others "are found, it seems probable to me that they are but what I "formerly alledg'd, the Disports of Nature. In some marbles "gotten near Holker in Lancashire, I have seen the exact shape "of a *Man*, and that in six inches compass. In some mines in "Derbyshire I have seen a substance bearing exactly the simili-"tude of a man's tooth, and that as big as a child's head, to "which was annex'd an Head which would have contain'd several "measures, and the limbs proportionable. In Pool's Hole there "is the resemblance of a lion, a dead man, a chair, and a flitch "of bacon; yet no man (I suppose) will assert these to be "Exuviæ, or the chair one of the household goods of the Ante-"diluvians."*

In the same work there is figured the earliest representation of a trilobite from the Carboniferous Limestone, and upon the same page is the figure of

"A stone taken out of the Bowels of a Man in Lancashire, and "covered with Spunge."

Dr. Leigh seems to have known Liverpool and its neighbourhood well, and from several statements in his work there can be no doubt that he practised as a medical man in the town.

The foregoing quotations show that the errors which were prevalent in the year 1700 are exactly those that are common among uninformed persons at the present time. There was no clear distinction made between fossils and mineral substances; a want of the power of discriminating specific differences; and an ignorance of the fact that it is only the hard parts of an animal, or the mere impression of the soft parts, that can be preserved in a fossil state.

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* Dr. Leigh, p. 115.

The belief in the Theological Deluge is observable in the arguments that are advanced, to account for the occurrence of the remains of animals and plants in the solid rock.

CARBONIFEROUS LIMESTONE.

The Carboniferous Limestone is not developed nearer than Flintshire. The formation as it occurs in that county has not been minutely described, though there are many brief notices referring to it. The following list contains the various contributions, arranged in the order in which they have appeared:—

"Analysis of One Hundred Parts of a Dark Bituminous Limestone, from the Parish of Whiteford, in Flintshire, North Wales." By E. D. **Clarke**, LL.D. Geological Transactions, vol. 4. 1816.

The Geological Survey Maps No. 79 N.E. and 79 S.E. contain the Carboniferous Limestone and the Flintshire Coal-measures, with numerous Lead Lodes. A Section, No. 43 across the latter map also illustrates the geology of the country.

"Report of the Excursion made by the Society to Holywell, July, 1861." By **Henry Duckworth**, F.G.S., F.L.S. Proceedings, Liverpool Geological Society, 1861-2.

"Palæontological Observations on the Carboniferous Limestone in Flintshire." By G. H. **Morton**, F.G.S. Proceedings, Liverpool Geological Society, 1868-9.

Brief notices of the Carboniferous Limestone of Flintshire occur in the "Geological Magazine," also in the "Geology of North Wales," by **Prof. Ramsay**, F.R.S. Geological Survey, 1865.

COAL MEASURES.

The Coal-measures which are so well developed in the neighbourhood of Liverpool, and doubtless exist beneath it, have for centuries yielded an abundant supply of coal.

The rapid consumption of timber towards the latter end of the 13th century caused the use of coal to become general at that time. Although there are few allusions to coal in the works of early writers who have referred to places in the vicinity of Liverpool, it is probable that the mineral was in common use 350 years ago.

In the reign of Henry VIII we are informed that

> "Mr. Bradshaw hath a place caulid Hawe, a mayle from "Wigan. He hath founde moche canel like se coole in his "grounde; very profitable to hym, and Gerade of Yuse dwelleth "in that parish."*

The Bradshaws seem to have been connected with the Cannel mines of Wigan for a very long period, as Dr. Leigh says:—

> "I was informed from my ever-honoured friend Sir Roger "Bradshaw of Haigh, that it was upon a whitish yellowish earth, "in a field near the kennel-pits of Haigh."† &c.

And again, after describing some

> "long parallel cylinders joined together,"

evidently *Calamites*, he says:—

> "These were first communicated to me by that honoured and "learned lady the Lady Guise, mother to the present Lady "Bradshaw of Haigh."‡

Early in the 17th century, and ever since, Cannel coal has been manufactured into a variety of ornamental articles, for it takes a fine polish. This coal, even before the discovery of gas, was always considered to be the most valuable, because of the great light it gave. It saved poor persons the necessity for candles, while it diffused a cheerful light in the apartments of the rich.

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* Leland's Description, "History of Lancaster," Edwd. Baines, vol. 3, p. 604, and "Baines' Lancashire," p. 542.

† Dr. Leigh, p. 57. ‡ Dr. Leigh, p. 130.

Early references to Prescot and St. Helens do not contain any allusion to coal, so that it is probable that the coal-seams were not worked there at such an early period as at Wigan. In 1707, however, we find almspeople receiving coal at Prescot.

It is very interesting to know the state of scientific knowledge regarding the stratification of the Coal-measures nearly 200 years ago, and Dr. Leigh gives the required information. He says :—

> "It is an observation as common as true, and which may "justly challenge our admiration, that the mines in all parts of "the world (I mean coal and kennel mines), are always found in "strata, shelving towards the centre; or, as the miners say, "dipping: inasmuch, that the same which in one part perhaps "cannot be discovered under 20 fathom, is yet at the rise of the "mine frequently found near the surface of the ground. These "generally keep the same dip as the coal that lies over them, and "by finding that you speedily disclose the mine; and whatever "the miners may pretend, so far as I have been able to observe, "more certain directions for the discovery of these mines cannot "be given."*

This petrological description of the coal-strata is so exact, that it is evident that the miners at the time of Dr. Leigh possessed the requisite knowledge for developing the coal-fields in the neighbourhood of Liverpool, particularly as he speaks of "Dikes, Riders, and Leaders"† as miners' terms, with which as geologists we are well acquainted, and says :—

> "that the things signified by these are observable in all the "mines which I ever saw."

With regard to the origin of the Coal-measures, the logic of his argument is sacrificed to the profound respect he entertains for the Deluge of Moses.

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* Dr. Leigh, p. 65. † Dr. Leigh, p. 118.

The coal-seams of Flintshire were worked so early as the reign of Edward the First. In the 17th century Dublin and other parts of Ireland were supplied from that source, and it is very likely that Liverpool may have received coal from the coast of the Dee.

Before 1780 the town was principally supplied with coal which was brought in carts from Prescot and St. Helens.* After the canals in the neighbourhood were made the quantity brought to Liverpool was much increased, but it is very remarkable that coal in 1780 was sold in the town at about half its present price.†

Before 1815 it was supposed that cannel and ordinary coal never existed under the same surface, but about that year five beds of coal were found at Kirk Hay, beneath the Cannel or King coal.‡ The higher beds were probably known long before, and it appears that the number and relative position of the coal-seams around Liverpool have been known fully fifty years.

The following is a list of communications that relate to the Coal-measures near Liverpool:—

"On the Geology of the Coal District of South Lancashire." By JAMES HEYWOOD, F.G.S. Report, British Association, Liverpool, 1838.

"On the Coal Measures of West Lancashire. By W. C. WILLIAMSON." Report, British Association, Liverpool, 1838.

"On the Dislocations of the Coal Strata in Wigan and the Vicinity." By WILLIAM PEACE. Report, British Association, Liverpool, 1838.

"On the Relation of the New Red Sandstone to the Carboniferous Strata of Lancashire and Cheshire." By E.

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* Baines' "History of Lancashire," vol. 1, p. 200.

† *Ib.*, vol. 1, p. 125.

‡ *Ib.*, vol. 2, p. 615.

W. Binney, F.G.S. Quarterly Journal, Geological Society, 1846. In this paper the strata at Sutton, Whiston, and Huyton are described.

The Geological Survey Maps No. 90, N. W. and 99, S.W. on both the 1 inch and the 6 inch scales.

"The Geology of the Country around Wigan;" and "The Geology of the Country around Prescot," both by Edward Hull, B.A., F.G.S. Geological Survey, 1860.

"On the Coal Measures in the Neighbourhood of Liverpool, and the Probability of their Extension beneath the Town." By G. H. Morton, F.G.S. Proceedings, Literary and Philosophical Society of Liverpool, 1861.

"The Geology of the Country around Liverpool." By G. H. Morton, F.G.S. Liverpool, 1863.

"On the Wigan Coal Field." By S. B. Jackson. Proceedings, Liverpool Geological Society, 1862-3.

"The Coal Fields of Denbighshire and Flintshire." By Edward Nixon, Mining Engineer. Proceedings, Liverpool Geological Society, 1865-6.

"On the Wigan Coal Field." By Alfred Hewlett, F.G.S. Journal, Liverpool Polytechnic Society, 1866.

"The Probable Source of Holywell Spring." By Robert Bostock. Proceedings, Liverpool Geological Society, 1867-8.

POST-PLIOCENE.

The first description of the Boulder-clay in the neighbourhood of Liverpool is a "Notice respecting the Pebbles in the Bed of Clay which covers the New Red Sandstone of the S.W. of Lancashire," by Dr. Bostock. Transactions, Geological Society, 2nd series, vol. 2. The paper was read in 1823. It contained a clear account of our Boulder-clay, with its pebbles, and boulders three feet or more in diameter. The author says "that the upper portion of the bed of clay, for about ten inches in depth, is obviously of a somewhat different nature from the great mass of it, being more sandy and of a lighter colour, and containing a great number of very small pebbles, although seldom any of the large ones." This upper bed he tells us is called "ravin."

The name Boulder-clay was given to the formation without reference to its supposed origin, which was then unknown. The term Glacial-drift is now often used. Since Dr. Bostock's contribution the following papers have been published:—

"On the Titaniferous Iron of the Mersey Shore." By Dr. J. B. Edwards. Report, British Association, Glasgow, 1855.

"Traces of Icebergs near Liverpool." By G. H. Morton, F.G.S. Proceedings, Literary and Philosophical Society, Liverpool, 1859-60.

The discovery of stones and boulders striated by the action of ice was first announced by myself before the Literary and Philosophical Society, in December, 1859. Proceedings, 1859-60. See also Proceedings, Liverpool Geological Society, 1859-60.

"On the Pleistocene Deposits of the District around Liverpool." By G. H. Morton, F.G.S., Report, British Association, Manchester, 1861. In this paper the Drift was divided into three sub-divisions.

"On Glacial Surface Markings near Liverpool." By G. H. Morton, F.G.S. Quarterly Journal, Geological Society, 1862.

"The Geology of the Country around Liverpool." By G. H. Morton, F.G.S. Liverpool, 1863.

"On the Presence of Glacial Ice in the Valley of the Mersey during the Post-Pliocene Period." By G. H. Morton, F.G.S. Proceedings, Liverpool Geological Society, 1866-7.

RECENT DEPOSITS.

Ascending to the most recent strata, overlying the Boulder-clay, there are distinct evidences of old land-surfaces or peat-mosses, below the level of high water mark, in many places on the coasts of Lancashire and Cheshire. Dr. Leigh describes the morasses which in his time occupied large areas along the western part of Lancashire, and states that exotic trees occur therein. He does not refer to the denuded edges of the morasses on the sea coast, some of which are now called Submarine Forest-beds, though from the account he gives, and the exactness of his descriptions, it seems very probable that he was familiar with such coast sections. He says :—

"The postures the Firr-stocks are found in, evince they "were brought thither by a deluge; I have seen seven or eight "of a vast thickness contiguous to each other, and whoever con- "siders the circumference of them must necessarily conclude "they could never grow there in that order, it being impossible "there should be a distance betwixt each tree for the ascending "boughs."*

Dr. Plot, who wrote in the year 1686, refers at considerable length to the opinions of numerous writers regarding the origin of trees found in peat-mosses, he says :—

"Now what sort of trees are these, whether mineral or vegetable? "and if vegetable of what species, and how buryed."†

It was discovered that such trees have no branches, and therefore could *not* be the remains of real trees at all, but Disports of Nature, and he describes other

"great difficulties that have disturbed many men's thoughts."†

He says :—

"I must distinguish between those found near the sea coasts "and those in the inland countries, the former no doubt being "overthrown and covered, either by the violent encroachments of "the sea if near the shoar, as those on the coast of Pembroke- "shire."‡

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* Dr. Leigh, p. 61. † Dr. Plot, Natural History of Staffordshire, p. 215.
‡ *Ib.*, p. 218.

Dr. Plot urged (quoted from Dr. Leigh),

> "that these morasses were the products of the woods that grew "upon them, which by the putrefaction of the leaves, rains and "dews, may, as we daily see, be converted into boggs or morasses; "and that the firrs found there were not brought thither by any "deluge, but were the product of the soil, and in probability "ruin'd by the Britains, in revenge to the Danes, the pines being "their darling tree."*

We have, you will observe, in this quotation the germ of the Lyellian doctrine regarding these Carbonaceous-beds.

Dr. Leigh refers to Hoylake, but only when he speaks of springs, as follows:—

> "Wherefore we rather assert what the great Aristotle supposes "concerning Springs, that they have their rise from the sea; of "this Cæsar had a clear demonstration when he invaded this "island, and encamp'd upon the sea coasts, where by digging in "the sands he was instantly supply'd with a sufficient quantity of "fresh water, which by filtring through the sand became sweet, "the saline particles sticking in the sand. A phenomena like to "this was observ'd when that great General Duke Schomberg "encamp'd upon a plain called the Mels, near Hile-Lake."†

Dr. Leigh figures the skull of a hippopotamus "dug up under a moss in Lancashire," also the head and antlers of a "Stag of Canada, found eight yards within Marle," in the same county. These he tells us sufficiently demonstrate the universality of the deluge.

In the "Topographical Description of Lancashire," by George Alex. Cooke, written above one hundred years later, the mosses or morasses of the county are described, and it is stated that "large trees are frequently found buried several feet below the surface, so well preserved from decay, by the exclusion of air, that they are capable of being worked into furniture. After penetrating quite through the moss-earth, or bed of peat, sand or clay is met with. It is very evident that these tracts were once forest-land, the trees upon which were destroyed by an inundation of salt water."

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* Dr. Leigh, p. 60. † *Ib.*, p. 29.

The earliest local geological communication appeared in the "Gentleman's Magazine" for July, 1796. It relates to the Submarine Forest at Crosby, and was contributed in the form of a letter from a Mr. George Holt, of Walton. He describes it as "extending upwards of a mile towards Formby. What might have been its original extent, either in that or any other direction, seems at present impossible to ascertain; but vestiges of it are visible dipping westwardly into the sea, which doubtless covers a great part of the land on which a considerable portion of it grew. There are numberless trunks of trees standing upright some feet above the surface, in the very place where they must have grown, with their prodigious roots extending into the ground in all directions in their natural positions."

Between the years 1821 and 1844, numerous papers were read before the Literary and Philosophical Society of Liverpool, which were never published. Only the following possess any local geological interest, and they are principally connected with dynamical geology.

"Reasons for the late Extraordinary Changes in the Bed of the River Mersey, with Suggestions for its Improvement." By T. JEVONS, 1827-8.

"Account of a Submarine Forest, on the Coast of Caernarvonshire and Radnorshire." By the REV. JAS. YATES, Cor. Mem., 1832-3.

"On the Horizontal Action of Tides in Liverpool Bay, and the datum afforded to Practical Science, by close observation of the Tides' Vertical Action." By CAPTAIN DENHAM, R.N., 1836-7.

"Comparative State of the Navigable Approaches to the Port of Liverpool, in an interval of four years." By CAPTAIN DENHAM, R.N., 1838-9.

"Geological Account of a Cave, near Holywell." By — LUCAS, 1838-9.

"Proposal for the Improvement of the Channel of the Mersey." By S. GIBSON, 1838-9.

"On the Rapid Changes which take place at the entrance of the River Mersey; and the means now practised for establishing an easy and direct access for vessels resorting thereto." By J. B. YATES, 1839-40.

After the twenty-two years in which the foregoing communications were read, the society began to publish a record of its proceedings.

In the British Association Report for 1837, there is no paper relating to the Post-pliocene or Recent Deposits. There was no paper on the New Red Sandstone; but Captain Denham, R.N., brought the following dynamical subject before the Geological Section.

"On the Tidal Capacity of the Mersey Estuary—the proportion of silt held in solution during the flood and ebb circulations—the excess of deposit upon each reflux, and the consequent effect produced by the matter thus detected in its transit, and measured at its lodgment, on the banks in Liverpool Bay."

In May, 1846, the Rev. A. Hume, LL.D., F.S.A., read a paper before the Literary and Philosophical Society of Liverpool, entitled, "An Account of the Antiquities found at Hoylake." It contains a geological description of the locality, and particularly of a section at Poulton Bridge, in the neighbourhood of the Submarine Forest, where the land was intersected by a road made by the Birkenhead Commissioners. Dr. Hume describes the section, but all I need give you are a few quotations relating to the most important points. "The upper surface to the depth of six or eight feet consists of alluvial deposits; and beneath this is a black mass similar to a coal-seam about six feet in thickness, composed of decayed leaves, branches, bark, and trunks of trees intermixed with hazel nuts, and the mast of other common inhabitants of the forest." There is no allusion to stumps of trees occurring embedded in the vegetable matter, but it is stated that, "the trunks were found lying with their roots towards Bootle Bay, and their tapering extremities pointing in a south-westerly direction." "From all appearances it is plain that on some day in autumn, as is evident by the number of nuts found, the sea, probably during a storm, accompanied by a high tide, has suddenly burst over some point near where Leasowe Castle now stands."

In 1849, Mr. J. A. Picton, F.S.A., read a paper before the same society, on "The Changes of Sea Level on the West Coast of England during the Historic Period." It was not printed *in extenso* in the Report of Proceedings, but I have it in manuscript, copied from the newspaper account at the time. The author refers to, and quotes Sir Charles Lyell's opinions regarding the destruction of old forests, and the formation of peat-mosses upon their sites.* He states that the peat-moss about Scarisbrick "dips towards the north-west; the drift sand taking its place on the surface until near the shore; about Southport the peat is found to lie at a considerable depth below the level of the sea." The Submarine Forest, known as Wycherley Wood, which existed seventy years ago a little north of the Prince's Dock, is described, and after referring to the encroachments of the sea on the shores of the Mersey and at Leasowe, he describes the Submarine Forest at the latter place with "the stumps of several hundred trees, situated in the exact position in which they grew." "That for the most part they present the appearance of having been cut down by the axe, and are principally oak timber."

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* Lyell's Principles of Geology, vol. 2, p. 498.

In the same year (1849) we have a letter written by Mr. J. P. G. Smith to the same society.* It is an important addition to previous information, for we have a very exact description of a section along a canal or drain twelve or fourteen feet deep, and in length about a mile and a quarter, from the Poulton and Bidston Road towards Leasowe Lighthouse. The section which is appended to the letter shows the following beds from the bottom upwards.

Boulder clay.

Stratum of white sand.

Forest trees in soil, stumps in situ, consisting of oaks, elms, alders, &c.

Irregular accumulation of peat, containing rushes, equiseta, &c.

Alluvium resembling the Wallasey Pool silt.

Surface soil.

The author considered that the trees had been cut down by the axe, "for, if they had been levelled by a storm of wind, they would have been torn up by the roots, not snapped off close to the ground, and at their strongest part."

"Such an accumulation of peat would be the natural result of the prostration of a dense forest upon a damp soil, and there is more than one instance upon record, of the accumulation and formation of a moss in consequence of the overthrowing of a forest."

"Some of the vegetable remains in the moss are very perfect, such as rushes, equiseta, &c., especially where the moss is the thickest."

Mr. Smith does not mention the occurrence of prostrate trees, though most probably they were seen.

After the letter had been read, Mr. Nisbet described how "the radicles and runners of different grasses had penetrated through every part of the trees in the peat, showing how completely they had been softened." Dr. Inman "objected to the idea that the prostrate trees had all been felled by the axe. Forests in other places had been known to have become converted into mosses, in which numerous trees were discovered, and where the instrumentality of man could not have been in operation. He considered that their fall was due to their trunks having become dead, saturated, and softened, by moist vegetable *debris* accumulating around their roots. In this condition they would be readily snapped by storms, which would have no effect on that part lying below the level of the moss."

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* Proceedings, Literary and Philosophical Society, Liverpool, 1848-9.

This explanation of the falling of the trees given by Dr. Inman, not only agrees with the opinions of Sir Charles Lyell in his "Principles of Geology," but it is the accepted theory of geologists. But no one could reasonably suppose that all the trees in the old forests were subjected to conditions exactly alike, and fell in precisely the same way. We must expect to find that they sometimes fell from other causes, and that the peaty bed in which they are embedded varies in its general aspect.

The following papers, by several authors, and a work by DR. HUME then appeared:—

"Notice of certain Mineral Springs at Leasowe." By the REV. DR. HUME. Transactions, Historic Society of Lancashire and Cheshire, 1848-9.

"On the Submarine Forest, Leasowe." By JOHN CUNNINGHAM, F.G.S. Report, British Association, Liverpool, 1854. This paper contains two sections obtained by boring.

"On some recorded Changes in Liverpool Bay, previous to the year 1800." By JOSEPH BOULT. Transactions, Historic Society of Lancashire and Cheshire, 1855-6.

"Notice of Mammalian Remains discovered in the excavation at Wallasey for the Birkenhead New Docks." By T. J. MOORE. Transactions, Historic Society of Lancashire and Cheshire, 1857-8.

"Topographical Notes of the Outline of the Sea Coast of Cheshire." By the REV. DR. HUME. Transactions, Historic Society of Lancashire and Cheshire, 1858-9.

"Report of the Society's Field Meeting, at Leasowe," By HENRY DUCKWORTH, F.G.S., F.L.S. Proceedings, Liverpool Geological Society, 1861-2.

"Ancient Meols, Antiquities of Dove Point and Sea Coast of Cheshire." By the REV. DR. HUME, 1863.

"The Pre-Historic Man of Cheshire, or some Account of a Human Skeleton found under the Leasowe Shore, in Wirral, and Appendix." By LIEUT.-GENERAL THE HON. SIR EDWARD CUST, D.C.L., 1863-4.

In "The Geology of the Country around Liverpool," (1863) the position of the Peat or Submarine Forest-beds is minutely described. Little is said about the peaty mass in which the stumps of trees are embedded, and still less with regard to the destruction of the old forests, which formerly covered the ancient Land-surfaces. The circumstances under which the lecture was published by the Liverpool Naturalists' Field Club rendered brevity a necessity. This work contains a *resumé* of several papers which have appeared in the Proceedings, Liverpool Geological Society.

The successive Peat or Forest-beds described are the following:—

Custom House Peat or Forest-bed—39 feet below high water mark—consequently 9 feet below low water mark of spring tides.

Nelson Dock Peat or Forest-bed—35 feet below high water mark—5 feet below low water mark of spring tides.

Wallasey Pool Peat or Forest-bed—29 feet below high water mark--consequently just above the low water mark of spring tides.

Lower Leasowe Submarine Land-surface—8 or 9 feet below high water mark at spring tides.

Upper Leasowe Submarine Forest-bed—3 feet below high water mark at spring tides.

All these old Land-surfaces seem to have been the sites of old forests, for they contain trees embedded in peat, usually including the marsh plants, which seem to have preceded or accompanied its formation.

Assuming a subsidence of the land to account for the depth at which the old Forest-beds are now found below the sea level, it is obvious that they became submerged one after another; those occupying the lowest level being first covered by the sea. The lowest of these surfaces are called "PEAT or FOREST BEDS" in the "Geology of the Country around Liverpool," and it seems certain that the previously existing forests had been destroyed and immured in their peaty coverings long before the submergence took place. The subsidence of land is usually a very gradual process, and we have no data for ascertaining whether the submergence of the Peat-beds of the Mersey was accomplished rapidly, in a few hundred years, or whether it occupied a longer period embracing thousands of years.

Geologists have strong objections to any theory necessitating a change of level during the last two thousand years.

Probably a variation in the range of the tides is sufficient to explain an apparent subsidence in the Upper Leasowe Forest-bed, though it could not have been to such an extent as to enable the Lower Land-surface to support the growth of trees.

The height of the tidal column at Liverpool is about 30 feet. Its height at the present time is the result of certain geographical conditions; under different circumstances the height of the tidal column at Chepstow is 60 feet, while a little south of Dublin on the Irish coast there is no rise or fall of the tide whatever. From these facts you will see that geologists are warranted in supposing that a variation in the range of the tides may explain some cases of apparent depression and elevation, and considerably reduce the amount in others. No change in the heights of the tides at Liverpool has been recorded.

The chief interest attached to the Leasowe Carbonaceous-beds, apart from their position below the high water level, is the interstratification of a blue silt between the two Submarine Forest-beds at Dove Point.

The following is a list of the works and papers that have appeared recently :—

"On the recent Shell-bed at Wallasey." By G. H. MORTON, F.G.S. Proceedings, Liverpool Geological Society, 1864-5.

"On the Alleged Submarine Forests on the Shores of Liverpool Bay and the River Mersey." By JOSEPH BOULT, F.R.I.B.A. Polytechnic Society, 1865.

"Fallacies and Incorrect Statements on the Subject of the Local Submarine Forest; their Exposure and Correction." (A reply to Mr. Boult.) By the REV. DR. HUME. Polytechnic Society, 1866.

"Changes in the Sea Coast of Lancashire and Cheshire." By the REV. DR. HUME. Transactions, Historic Society of Lancashire and Cheshire, 1865-6.

"Further Observations on the Alleged Submarine Forests on the Shores of Liverpool Bay and the River Mersey." By JOSEPH BOULT, F.R.I.B.A. Transactions, Historic Society of Lancashire and Cheshire, 1865-6.

"Speculations on the former Topography of Liverpool and the Neighbourhood." By JOSEPH BOULT, F.R.I.B.A. Parts 1 and 2. Polytechnic Society, 1866-7.

"A Record of Archæological Products of the Sea Shore of Cheshire in 1864." By H. E. SMITH. "Reliquary" Quarterly Archæological Journal and Review, 1865.

"Notabilia of the Archæology and Natural History of the Mersey District during 1863-5." By H. E. SMITH. Transactions, Historic Society of Lancashire and Cheshire, 1866-7.

"Archæology of the Mersey District, 1866." By H. E. SMITH. Transactions, Historic Society of Lancashire and Cheshire, 1866-7.

"Observations on the Cheshire Coast." By CHARLES POTTER. Proceedings, Liverpool Geological Society, 1868-9.

In Dr. Hume's "Ancient Meols," the Submarine Forest-beds of Leasowe were minutely described in connection with the Antiquities of Hoylake. Mr. Boult's papers "Observations" and "Further Observations," were written to controvert the opinions of Dr. Hume and others with regard to the old Forest-beds of Leasowe. In these papers, as well as in his "Speculations on the former Topography of Liverpool," we have strung together a collection of interesting facts, bearing more or less upon our local geology, which are well worth reading and preserving for reference. The author has tried hard to show that the trees embedded in the old Forest-beds did not grow on the spot, and that the vegetation came drifting from some other locality to the place where it now occurs. Many members of this and other societies have been at Leasowe, heard his arguments, and estimated them for whatever they are worth. Mr. Boult's theory would have been more successful if he had kept away from the Submarine Forest altogether, for his hearers seem to have come home with a settled conviction that he was wrong. However, we are indebted to him for illustrating his views on the old Forest-beds.

The latest communication I have to notice relating to the Submarine Forest-beds is the one by Mr. Potter, entitled, "Observations on the Cheshire Coast."

The author gives a lithograph of the strata exposed along the shore at each side of the Leasowe Embankment, with a description of the well-known eight beds that occur at Dove Point, beginning with the Boulder-clay and including the Submarine Forest-beds and other similar strata. The author agrees with the arrangement adopted in "The Geology of the Country around Liverpool," but has found it necessary to alter the name of each stratum.

At the other side of the Embankment near Leasowe Castle, there are some Peat-beds and other strata to which little attention has hitherto been given; for they are not well exposed, being partly buried in sand, and do not at first sight appear to possess much interest.

Mr. H. Ecroyd Smith gave a section of these beds in his "Archæological Products," (1865,) at the place where the human skeleton was found in 1864. Mr. Smith's section exhibits two Submarine Forest-beds at some distance beneath the surface. Close to the spot a boring was lately made to the depth of 9 feet 6 inches below the "Peat-bed destitute of trees." Instead of passing through the two Forest-beds, the boring did not reach the bottom of the Blue Silt. Mr. Smith has since informed me that the two Submarine

Forest-beds occur more to the N.E. along the shore, and that he should have expected them where the boring was made.

In the lithograph appended to Mr. Potter's paper eight distinct beds are inserted at the Leasowe Castle end of the embankment, and they are correlated with the Dove Point strata in their regular order of succession from the Boulder-clay upwards. The strata at Leasowe Castle appear so very different compared with those of Dove Point, that the author has not done himself justice by merely giving a section showing the strata, and only vaguely referring to them instead of giving an exact description.*

Several pages of Mr. Potter's paper are devoted to the author's observations and opinions regarding the timber, butts of trees, and the peaty strata in which they are embedded. At page 43 he describes prostrate trunks "lying upon and crossing each other *at every conceivable angle* and depth in the bed; while the roots of the standing butts are as often above as below them." At page 45 he says, "and yet in no case do their overlying roots fashion or adapt themselves to those they rest upon." The author observes at page 44, "that the horizontal trunks of the trees are found in the very lowest part, and through the whole bed, until they rise or project above the surface, is proof that they were being deposited during the whole period that these beds were being formed." At page 44 we are told that "in no part of these is there any indication of vegetable earth." At page 47, after saying "that the superficial observer is almost certain to come to the conclusion that they (the trees) are as they have grown," he says, "But on closer examination and digging out they will be found to tell an entirely different tale." These quotations are given for what they are worth. There are several pages in the paper explanatory of the observations of the author, which have no doubt taken him a considerable time to work out, and he has certainly told us a great deal that we did not know before, yet I cannot see that he has brought forward any facts at all sufficient to support the extraordinary theory of Mr. Boult, and since adopted by himself, that the trees of the Submarine Forest drifted into their present positions. With regard to their being *in situ* we have the most satisfactory evidence, and cannot assume that the numerous individuals who have gone to Leasowe and most carefully examined the stumps and roots of the trees have been "superficial observers." There may be, and we must expect examples of trees having been broken at their roots, and sometimes even torn up altogether and left in a prostrate condition. The more we extend our observation over these Peat and Forest-beds, the less likely we shall be to have confined and erroneous opinions regarding them. There is not an apparent quotation in the author's paper, except those descriptive of a tropical hurricane. The single reference to "The Geology of the Country around Liverpool," page 45, is a mis-statement connected with somebody's wild theory about the trees of the Submarine Forest having rotted their tops off in water. We are told at page 50, "It has been argued that the water has risen gradually on these trees, and that it has remained long enough to rot them all at the height at which they now stand."

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* The Leasowe Castle end of both Mr. Smith's and Mr. Potter's sections have since been found to be very inaccurate, Mr. Isaac Roberts having bored to the Boulder-clay in numerous places along the shore, without finding the two lowest Peat or Forest-beds.

If the author had studied Lyell's "Principles of Geology," Dr. Rennie's "Essays on Peat," and other works descriptive of the peat-mosses, embedded and submerged forests, it is difficult to suppose that his paper would have been written. If it had been under those circumstances he would have hardly thrown away his energy in attacking an unwritten argument, but would have replied to the accepted theory of Sir Charles Lyell regarding such deposits. As it is, he has endeavoured to master many imaginary difficulties connected with the Leasowe-beds, while the simple geological facts seem to have mastered him, and he has left the subject exactly as he found it.

From the numerous papers and other contributions that have been noticed, you will perceive that the literature relating to the Submarine Forests and Peat-beds in this neighbourhood is very voluminous, and extends over a period exceeding seventy years.

In conclusion may be given the opinion of geologists regarding Peat-beds and Submarine Forests, presuming that they originated in the same way in the various parts of the United Kingdom where they occur, although at different periods of time. Peat-beds, or Carbonaceous-beds of any kind, containing stumps of trees, seemingly *in situ*, are usually called Submarine Forests when they are exposed between the range of the tides on the sea shore, or in an estuary. No distinction can be drawn between inland peat-mosses, with embedded timber, and those Submarine Forests where the stumps of the trees are usually denuded of their peaty covering, which appears seldom to have accumulated to any great thickness along the margin of the land, where its development seems to have been arrested by tidal influence, or subsidence beneath the level of the sea. Sir Charles Lyell, referring to trees at the bottom of peat-mosses, says that "they have been so often observed with parts of their trunks standing erect, and with their roots fixed to the subsoil, that no doubt can be entertained of their having generally grown on the spot."* These old forests are considered to have been destroyed by obstructed drainage; the growth of moss around the roots preserving, though softening, the stumps, while the upper parts of the trees fell by the ordinary operations of nature, and soon became immured in peat. The complicated growth of generations of trees in a forest; old trees falling to the ground and new ones taking their places; the conversion of the area into a marsh introducing plants peculiar to such situations; the introduction of moss and the formation of peat; and the gradual destruction and final overthrow of the forest by various atmospheric agencies; have produced considerable variation in the position and aspect of the compact mass of vegetation exhibited in sections of these deposits. When the evidences of such changes in condition are apparent in Peat-beds with embedded timber, the conclusion that the trees and other plants grew on the spot is irresistible. As may be expected, we find sections of less interest, such as Peat-beds without trees, stumps and prostrate trees with little or no peat. There is nothing in such examples to excite surprise, or to throw doubt upon our conclusion regarding the origin of such deposits. The inland Peat-beds and mosses have never been covered by the sea, and seldom by fresh water excepting within very restricted limits. The old Peat and Submarine Forest-beds are covered in many parts of our coasts by a considerable depth of water at high tides, and some are below the level of the low water line of spring tides. The trees of these Submarine Forest-beds seem to have been destroyed and covered with peat long before they became submerged, and it is improbable that it should have been otherwise.

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* Lyell's Principles, vol. 2, p. 498.

I must finally direct your particular attention to the improbability (I might almost say the impossibility) of any aqueous transportation and deposition of vegetation depositing a bed of peat, either with or without trees spread out as we find them in these Peat-beds and Submarine Forests. We have no parallel example on record—nothing like it in creation. There are both recent and geological instances of the transport and deposition of vegetation at the bottom of the sea. The Mississippi carries down vast quantities of trees into the Gulf of Mexico, but it cannot form anywhere a continuous bed of vegetation unmixed with sedimentary matter. In the Coal-measures we occasionally find in the sandstones and shales clear indication of great accumulations of trees and smaller plants, but we do not confound them with seams of coal, for they bear no resemblance to the great Submarine Forests of the Carboniferous era. In the former case we find a matted mass of vegetable impressions traversing a stratum of some shaly or sandy rock, while in the latter we have a solid bed of coal with the roots of trees underlying it. In the Oolite and Tertiary strata we find little or no difficulty in deciding whether a Carbonaceous-bed is of aqueous origin, or whether it represents a land-surface like the Portland dirt-bed with imbedded tree stumps. With regard to our recent Peat-beds and Submarine Forests, there is no reason whatever to suppose that they can have originated by any kind of aqueous transportation. Sir Charles Lyell, after referring to the Irish peat-mosses, and to those of England, France, and Holland, describes the marsh of Curragh in the Isle of Man, where vast trees are discovered standing firm on their roots, though at the depth of 18 or 20 feet below the surface. "Some naturalists," he says, "have desired to refer the embedding of timber in peat-mosses to aqueous transportation, since rivers are well known to float wood into lakes; but the facts above mentioned show that in numerous instances such an hypothesis is inadmissible.*

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* Lyell's Principles, vol. 2, p. 498.

I have trespassed considerably upon your time by introducing a subject of a very elementary character for a Geological Society. Circumstances, however, seemed to require some decided expression from this chair regarding the origin of the Submarine Forests on our coast. It has afforded me an opportunity of saying all that I have to say on the subject, and it is to be hoped that the discussion of it is now closed, for we can ill afford to go back to theories which "disturbed men's thoughts" two hundred years ago.

We have before us the approaching visit of the British Association. Since the meeting in Liverpool in 1854 this Society has been formed, and we shall be expected to contribute largely to the proceedings of the geological section. We must also help in every possible way to ensure the success of the meeting, so that one of the earliest duties of your new council will be the consideration of a donation for the purpose of promoting that object.

NOVEMBER 9TH, 1869.

THE PRESIDENT, G. H. MORTON, F.G.S., in the Chair.

J. F. CALLENDER was elected an Ordinary Member of the Society.

MR. BOSTOCK announced the observation of Ice Markings in Tranmere Valley—the striæ running in the direction of the Valley—exactly magnetic north, at an elevation of 98 feet.

The following communication was read:—

GEOLOGICAL OBSERVATIONS IN THE NEIGHBOURHOOD OF EXETER.

BY CHARLES RICKETTS, M.D., F.G.S.

THE rocks forming, in a great measure, the foundations on which the City of Exeter rests, at least in its highest parts, have been referred to the Trias, but differ greatly in lithological character from those of the same period in our own neighbourhood. They are seen on ascending the hill, immediately on leaving the Bristol and Exeter, or St. David's railway station, resting upon highly inclined and greatly denuded surfaces of the Culm-measures or Carboniferous formation, which there consists of a succession of beds of shale, so far altered into slate that they split into needle-shaped fragments in a direction varying from the dip of the strata at a considerable angle; these are separated from each other by beds of Sandstone, unaffected by cleavage, showing the angle of the dip to be 75° to the north.

The Triassic rocks, of which many of the buildings are composed, lie horizontally on these almost perpendicular strata, and consist of a coarse pebbly Conglomerate, of a deep red colour. Frequent exposures of these rocks can be seen in the higher parts of the city, but the building stones have been obtained from an extensive quarry about a mile and a half distant in an easterly direction, a little beyond Heavitree. The pebbles entering into their composition have been derived from various kinds of rock—quartz, granite, porphyry, trachite, sandstone, &c.—chiefly of small size, but with the occasional occurrence of larger ones. Those which have been derived from igneous or granitic rocks greatly preponderate over those which can be referred to a sedimentary origin. All of them are of an angular or sub-angular character; none of them have been rolled, and the appearance of those in which the angles have been removed must be attributed to subaërial exposure; certainly not to attrition on a sea beach or in the bed of a river. To determine the origin of these pebbles would require an extensive survey of the district; some might probably be referred to the granites, such as are in the neighbourhood of Dartmoor; some appeared to belong to the culm-measures metamorphosed by heat, whilst others might possibly be referred to the volcanic outbursts which have occurred in the neighbourhood.

The strata in the cliffs at Budleigh Salterton, five miles east of Exmouth, were described; they are situated much higher in the series of Triassic rocks than those at Exeter or on the west side of the Exe, and are remarkable as containing a thick bed (100 feet) of rounded quartzite pebbles derived from the disintegration of some much older formation, which, from the organic remains contained in them, have been variously attributed to the Silurian and Devonian periods. The examination of their Brachiopoda by Mr. Davidson tends to prove that the great bulk at least of these pebbles are of Devonian age. A paper by him was read before the members of the British Association at its meeting at Exeter (since published and the fossils figured in the Quarterly Journal of the Geological Society, vol. xxvi, page 70), and attracted much attention. Many of the fossils have been also described by Mr. Salter, in the Quarterly Journal of the Geological Society, vol. xx, page 286, and Mr. Vicary has given a description of the Pebble-bed in the same volume, page 283. To these papers reference is directed.

It will be observed that there is marked upon the geological map the occurrence of several patches of Trappean rock situated at the juncture where the Trias overlies the culm-measures. The only one examined was that at Pocomb, a mile to the westward of the St. Thomas' station of the South Devon Railway, where volcanic rocks, of a dark reddish brown colour, lie in three bands; the lowest is of a vescicular character; the vescicles are generally small, though some are of larger size, and are filled with a light green substance. The middle is a bed of volcanic ash, and is traversed in every direction with fissures, which have been filled up with Carbonate of Lime, whilst the uppermost band is similar to the lowest. These beds rest upon the culm-measures, having intervening a band of breccia of the same, cemented together by what appears to be burnt clay.* At the further extremity of the quarry, traversing a portion of the lower band, are small nodules of vescicular lava, irregular, but somewhat rounded in shape; they are embedded in a matrix similar to that which encloses the fragments of the brecciated culm-measures.

The history of these rocks appears to be, that the culm-measures having been upheaved were exposed to extensive denudation, but prior to the deposition of the Trias, volcanic activity occurred in this locality, of which in the two bands of vescicular trap we have the record of two lava flows, with an interval of eruption between them, represented by the volcanic ash-bed. The first lava flow appears to have passed over a wet, muddy deposit, the superheated steam arising from which has displaced the cracked and broken fragments of the Carboniferous rocks, the interstices being filled up with the muddy deposit, which has afterwards become baked by the heated lava.

The nodules, though irregular in shape, have the appearance of volcanic bombs, but occurred in such a restricted area that it could not have formed the crater of a volcano. It seems probable that, whilst the lava flowed over rocks covered with water and mud, considerable quantities of steam were evolved, which, forcing for itself a passage through the lava bed, tore away fragments of the molten rock, throwing them upwards into the air, many of which again fell into the cavity which had been formed; the boiling mud would likewise have been ejected at the same time and fill up the interstices between each nodule.

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* Sir H. J. De la Beche (Report on the Geology of Cornwall, Devon, and West Somerset, page 203), says that the igneous rocks of Castle Hill, Exeter, on being exposed about 1836, "were found to be singularly intermingled with marl and sandstone."

DECEMBER 14TH, 1869.

THE PRESIDENT, G. H. MORTON, F.G.S., in the Chair.

EDWARD H. ROBERTSON, P. P. WILLIAMS, W. REID, and W. R. McCAIG, were elected Ordinary Members of the Society.

The following communications were read:—

THE CHEMISTRY OF GRANITE, AS ILLUSTRATING THE ORIGIN OF GRANITIC ROCKS.

BY A. NORMAN TATE, F.C.S.

THE author gave a *résumé* of such chemical investigations and discoveries as relate to granite and the minerals of which it is composed, including not only analytical researches as to their composition, but also such experiments as have been made to endeavour to form these minerals artificially. He particularly called attention to the papers of Professor Haughton, "On the Granites of Ireland," and the chemical and microscopical researches of Mr. Sorby, and likewise alluded to the late discussion between Dr. Sterry Hunt and Mr. David Forbes, agreeing, however, for the most part with Mr. Forbes.

THE FORMATION OF METALLIFEROUS VEINS.

BY ALFRED MORGAN.

THIS paper was intended to be a *résumé* of the usually received theories on the formation and filling of metalliferous veins, and at the same time introductory to other communications which Mr. Morgan intends making to the society. After referring to those treatises which have been written on the subject, among which are the valuable researches of Mr. R. Were Fox, Sir H. de la Beche, MM. Daubrée, Elie de Beaumont, Bischoff, &c., Mr. Morgan made some observations on the large amount of careful investigation it has received at the hands of continental *savants*, from the time of Werner at Freiburg to our own day. This is probably due to the fact that the majority of the mines on the continent are State property, and are worked under the control of efficient Governmental mining corps. The author then remarked that the same mechanical, chemical, and electrical forces are still in operation that acted originally in the formation of ore-veins. No geologist now doubts that metalliferous veins were primarily fissures. And, in support of this hypothesis, Mr. Morgan cited the invariable coincidence of veins with ordinary faults, and exhibited sections of a mine in Cornwall showing the lateral displacement of the veins from this cause. Among other evidence, he mentioned that the opposite walls of a vein are frequently *slickensides;* that they sometimes contain well-rounded pebbles and shells, which have evidently been derived from the surface; and, that a parallelism of direction is maintained. Mr. Morgan then referred to the filling of veins by means of sublimation, and pointed out that this means may have performed an important part in the production of ores. With respect to the filling of cavities with metalliferous matter by segregation from the surrounding rocks, the author quoted instances in which the spaces originally occupied by fossil organisms had been refilled with metallic substances, such as copper-pyrites and sulphuret of lead. He observed that, though it is probable that all rock cavities have a tendency to be filled with mineral matter, by means of infiltration, it is necessary to take into account other conditions in the case of fissures of such vast extent as mineral veins. That some such fissures were at one period the channels by which hot-springs holding the various metals in solution made their way to the surface will probably not be doubted. Mr. Morgan referred to the increased solvent power of water as we may suppose it existed at great depths, and under conditions of increased temperature and pressure. He then noticed the uniform nature of the elements of volcanic emanations, thermal springs, and mineral veins. He thought some geologists spoke rather presumptively of the mid-terrestrial region. But, little as is known of the central portion of our planet, it is certain that the mean density of substances there is much greater than at the surface. After pointing out that the mineral contents of thermal springs and mineral veins might be expected to differ in some particulars, the author proceeded to show that it is only by taking into account all these agencies, viz., the action of thermal springs, segregation, volatilization, and conditions of increased temperature, pressure, and chemical action and reaction that we can offer any adequate explanation of the origin and arrangement of metalliferous deposits. Mr. Morgan concluded his paper by referring to the action of electricity, which has, to a large extent, determined the nature of the metallic deposits. He exhibited a section of the Derbyshire limestone with interposed trap-rocks, locally termed *toadstones.* The same vein which is rich in the former may be almost unproductive in the latter. A similar phenomenon is observed in Cornwall, where the nature of veins is very greatly affected as they pass through granite or killas.

JANUARY 18TH, 1870.

THE PRESIDENT, G. H. MORTON, F.G.S., in the Chair,

Thomas Clegg was elected an Ordinary Member of the Society.

Mr. Charles Potter exhibited a valuable and interesting collection of relics from the Leasowe Shore, consisting of buckles, beads, seals, horse furniture, and about one hundred coins, dating from Edward the Confessor to Edward III, chiefly of the last reign. He stated that during the past year sixteen yards has been washed away from the sandcliffs on the Leasowe Shore; the landmark at Dove Point having been removed twice farther inland. This he stated was exceptional, the ordinary rate being about three yards per annum.

The following communication was read:—

FURTHER OBSERVATIONS ON THE CHESHIRE SHORE, WITH A REVIEW OF PAST INVESTIGATIONS.

By Charles Potter.

FEBRUARY 15th, 1870.

The President, G. H. MORTON, F.G.S., in the Chair.

The following communications were read:—

AN EXPLANATION OF COTTA'S ARRANGEMENT OF ROCKS.

By G. H. Morton, F.G.S.

RECENT OBSERVATIONS IN GLACIAL AND POST GLACIAL DEPOSITS.

By H. F. Hall, F.G.S.

MARCH 8TH, 1870.

THE PRESIDENT, G. H. MORTON, F.G.S., in the Chair.

The following communications were read :—

THE MERSEY AND THE DEE—THEIR FORMER CHANNELS AND CHANGE OF LEVEL.

BY ROBERT BOSTOCK.

WHAT is thought about the courses of rivers, their present or former levels, may appear to be a matter of the utmost indifference. Even should erroneous views prevail, it seems scarcely worth taking the trouble to controvert them. But there is this to be said,—so long as false views of natural phenomena are held, there is the possibility that sooner or later these may become embodied and take a practical shape, when, as a matter of course, disappointment and loss of wealth, if nothing worse, must of necessity ensue. We have a case in point in our own neighbourhood which may serve as an illustration of this :—Some forty years ago, in consequence of letters in the press and discussion thereon, Liverpool people became imbued with the idea that they were about to be overwhelmed by the sea, by way of Wallasey Pool. Public meetings were held, followed by application to Parliament, ending in the formation of the present Leasowe Embankment. This was made at a cost of about £20,000; and although several thousands per annum have been expended there, it appears to have been insufficient, for there is now an accumulated debt upon it of about £20,000, and the expense is still going on.

The reasons given for the formation of this embankment were, that there were nearly 3,000 acres of land about Wallasey below the range of the tide, and the danger apprehended to the docks and town of Liverpool; but the question arises as to how it happened that these were not overflown when there was nothing whatever to prevent it. We have had several unusually high tides recorded within the last 100 years, but nothing said as to the destruction of land or property, so that it could not have been made to prevent a recurrence of something which had happened previously. If at that time there were reasons for thinking that a change was taking place in the relative level of land and water, if the land was thought to be sinking or the water rising there would have been some meaning in it, otherwise there is none. And it appears that from the fact of there being Peat-beds and the Old Forest on the shore at Leasowe below the range of the tide, with other reasons, it was concluded that it was only a question of time before the whole would be submerged.

But supposing it to have been the case that the sea really was encroaching on the land, an embankment would be quite useless in averting this. At most, it could only serve to put off the evil day which must come eventually, and with greater force the longer it was delayed. The better plan, perhaps, would have been to have raised the surface somewhat with soil from a distance, so as to keep pace with the rising waters. So regarded, the Leasowe Embankment can only be looked upon as a result of groundless fears; its making and maintenance simply a waste of money. Plain and self-evident as this may appear, public opinion at present would seem to be against it, for whatever I have heard or met with, either in conversation, papers, lectures, public enquiries on various questions, in literature, be it History, Geography, Geology, Topography, all that has reference to the physical condition of this district goes on the assumption that a subsidence of the land has taken place quite recently, and that it is still in progress. So the public may be said to have some excuse for their alarm, but whether those who write and speak of this subsidence have any grounds for such an opinion must be our next enquiry.

The evidence usually adduced in favour of this view is that of the Peat-beds or old land surfaces met with at various levels beneath the present high-water mark, and the washing away of the cliffs in the Estuary and around the shores of the Mersey. The fact of the Romans nct having made mention of the Mersey has led historians and others to doubt as to whether the river could have had any existence at that time. Others, again, think that if there was such a river in Roman times, probably it may have found its way to the sea by some other than its present channel, but all imply a change of level.

As to the Peat-beds, that numerous interchanges of sea and land have taken place no geologist could for a moment deny; that each of the Peat-beds must have been dry land whilst in course of formation is equally certain; but who can tell within thousands of years when these were submerged, or who can say what the last movement was, or whether it was upward or downward, or what the next one will be, and what evidence have we that the land is now sinking?

There are a few matters I will now submit to you which seem to me, however, to favour the view that no change of level has taken place in this neighbourhood for several thousand years.

Doomsday Survey was made 800 years ago, and in that mention is made of several towns and villages in this vicinity, the sites of which had evidently been chosen with reference to the sea line. I may mention Poolton. This is situated about two miles up Bromborough Pool. This, like all other pools in the Mersey, is not a pool in the proper sense of the term. It is a tidal pool—a pool when there are high tides; at other times it is merely a small stream. Poolton is situated up this, just at the point where it ceases to be affected by the tide. There appears no reason why it should have been placed there in preference to anywhere else, except that at that particular part it was possible to ford the stream at all times. Now, if at the time Poolton was founded the mean level of the sea had been lower than at present, there could have been no pool; consequently, if there was no pool, there could have been no Pool-town.

The same may be said of the two villages of Meols. Etymologists have not yet given us a satisfactory derivation of the term Meols—or Melas, the Doomsday term—but seeing that the words Meols and Hoos are never met with but when sand-hills abound, we are perhaps warranted in concluding that the name is descriptive and has reference to the sand-dunes. When these villages were built, a thousand years ago, it seems but reasonable to suppose that they were surrounded by sand as at present; but if the sea had been lower at that time it could not have been the case, for if the sea was lower, the shore must of necessity have been further seawards. If so, the sand-hills must have been further seawards also, inasmuch as they are dependent on shore conditions for their formation; consequently the term Meols applied to these villages would have been a misnomer.

There is the town of Bretton also; this is up the Dee, about three miles west of Chester. The turnpike road at the entrance to this is marked on the Ordnance Map as being but 18 feet above low water mark; in fact it is below the highest range of the tide, and during winter much of the land thereabouts is covered with water. Although this town is now upwards of a mile from the river, when built the shore was within a few yards of it. The Boulder-clay on which it is situated is only two or three feet above the tide. When this site was chosen if the sea had stood at a higher level it could not have been made at all; if at a lower one there is no reason why it might not have been built on the alluvium, as most of the new part of the town is. In this case we are assured that there has been no change, either way, to the extent of two feet. This place is also mentioned in Doomsday Survey.

We may go still further back in time. There is Chester. This must have been a town, great or small, even before the Roman era, for they speak of "going to" Chester—or Deva, as they called it—showing that there must have been a settlement of some kind there for at least *two thousand* years. The Roman mode of crossing the Dee was by fording, just below the Old Bridge, where the bed is rocky, wide, and shallow. They had also a boat for use during tide-time. This is exactly what would have to be done now, if there were no bridges. Now if, during the Roman period, the sea had stood at a higher level, it would have been impossible to have forded the Dee at any point near Chester; if at a lower one, there would have been no occasion for a ferry-boat. From this we learn that the mean level of the sea has not altered since then, not even to the extent of a foot or two, for this—small as it is—would render fording impossible or a boat unnecessary.

Should the argument as regards the Chester Ford be deemed satisfactory, of course it would be useless to argue against the opinion that the land is now subsiding; nor is it necessary to say much as to the supposed former channels of the rivers, inasmuch as this is said to be consequent on a change of level; but we may *en passant* just refer to it to show how self-contradictory and how very superficial many observations must have been. Thus, the historian who argues that as the Romans have not mentioned the Mersey there could not have been any such river, also alludes to the Roman fords at Lachford—or the Marsh-ford—near Warrington, and Stretford or the Street-ford, below Manchester, as though he was not aware that these are on the Mersey. The Romans may have known little or nothing of its lower reaches or outlet, nor is this to be wondered at when we consider that so lately as 1680 very little was known of it, for Captain Collins at that date speaks of great ships—that would be those of 50 tons burthen, probably—coming to anchor at Highlake to lighten, so as to cross the flats or shoals to Liverpool. There was another channel, he said, past Formby, but as it was not buoyed it was unknown and unused. This, which was in reality the channel of the Mersey, was not known even to those who lived within sight of it.

To think or speak of the Mersey as having been much what we now behold it for thousands of years, seems to be too commonplace; consequently those who describe it exhaust their ingenuity in describing new and out-of-the-way routes for it. One writer conducts it a mile or so up the valley of the Gowy, a rivulet which falls into the Mersey at Stanlow Abbey, a little above Eastham—then through a narrow vale branching off this, along which the canal runs, into the Dee below Chester. This is in effect to say that a twig of a tree might formerly have been the trunk. Another speaks of the Mersey as having formerly ran up Wallasey Pool, and discharged itself through a valley at Thurstaston into the Estuary of the Dee. Indeed, so anxious are they to convey it by some other than its proper course that they even make it run up-hill, for the rocky bottom of this Thurstaston valley is exactly 100 feet above the Mersey.

Similar views prevail respecting the Dee. The present channel of the Dee from Holt Bridge—ten miles above

Chester—is said to be artificial, and to have been formed by the Romans. Its previous course, they say, was below Gresford, by way of Kinnerton, Broughton, and Hawarden, to the sea near Flint. Merely to mention such views is a sufficient refutation.

Then as to the wasting away of the cliffs, supposed to be owing to encroachment of the sea, may not this be due to shifting sand-banks and the ever varying wind-floods and tides? In fact, it is a matter of history that most of the damage done has occurred during high tides accompanied by storms; besides, this encroachment theory is quite peculiar and limited to the dwellers on the Mersey; those by the Dee see things quite in a different light. One of the articles in a Cestrian's creed is to believe that Chester was formerly a great seaport, and that its present stranded condition is owing to its being deserted by the sea, and consequent silting up of the estuary. It seems strange and unaccountable that such contrary views should be held by people almost within sight of each other. One would have thought that this attributing such opposite effects to the sea in places so near would have occasioned some misgivings as to the conclusions arrived at; but they appear not to have perceived it, nor is it likely they will do so hereafter. Chester people will still go on enclosing the estuary of the Dee until they arrive at Hilbre, owing, as they suppose, to the "retreat of the sea;" whilst those in Liverpool will doubtless contribute their thousands annually to keep up the Leasowe Embankment against its "advance."

To conclude: What the valleys of the Mersey and Dee reveal to us of their own history, or what we might infer from an examination of them, is this—that the whole drainage area of both rivers, extending over thousands of square miles, has reference solely to the present channels.

As regards change of level, previous to the deposition of the Boulder-clay, the sandstone which then formed the general surface appears to have been denuded, in and near the river channels, to a depth of about 200 feet below the present sea-line; and we infer that the mean level of the sea must have been a little lower than that. The whole was afterwards laid under water, and the valleys all filled up with clay, this same Boulder-clay being now met with in places at an elevation of 1,400 feet. If we suppose this clay when laid down to have had a pretty uniform surface, it follows that this part of the country must then have been covered up to that extent. However, when it became dry land this began to be washed away, which wasting process continued until the surface near the river channels was about on a level with our present low-water mark, which mark must then have been that of high water. Since then the water has risen, or the land sunk, until it has attained to the present tidal range, which is about 30 feet, during which period all the alluvium or blue silt has been laid down, together with the Peat-beds interstratified with it and submerged. Then as to the submergence, did it take place in a uniform manner or periodically? The evidence is in favour of the latter. The peat itself is a proof that there must have been pauses; otherwise there would have been nothing but silt, without any appearance of vegetation only such as we may suppose floods might have brought down. We appear to be in one of those pauses at present. There is scarcely one of the valleys branching off from these rivers which has not near its mouth peat, or what will ultimately become such; but when the last submergence occurred, or when the next one will take place, we have no evidence—at least, I have none.

ON DEEP SEA DREDGINGS IN THE ATLANTIC.

By Rev. S. Cooke, M.A.

These dredgings, carried on off the coast of Florida, in America, in lat. (about) 25° N., and between the Shetland and Faroe Isles, lat. 59° to 60°, and off the coast of Norway, and also near the Azores, have not only thrown much new light on the fauna of the deep seas, but have also opened many very curious questions connected with the received theories of geology.

They have been carried on, apparently, chiefly in the bed of the Gulf Stream, or near it, as it divides itself into different branches in its easterly course across the Atlantic; one of these directed towards the N.E. by the N. of Scotland and the coasts of Norway, another bending S.E. by the Azores, &c., &c.

One result has been to shew a considerable similarity in the Fauna of those widely separated places where the dredgings have been carried on—due, probably, to the similar temperature of the water of the Gulf Stream everywhere; and another result of very great interest has been to shew that the peculiar deep sea fauna of the Gulf Stream is far more closely related to the faunas of the Tertiary and especially of the Cretaceous epochs than to those of the present time. In fact, the larger proportion of their organisms, mollusks, echinoderms, and zoophytes, are new, but related to those antique types, and some are even said to be specifically the same with them. Agassiz on the American side, and Carpenter on ours, have been engaged in these dredgings, and the results of their investigations curiously support each other, although they had to deal with conditions (in some respects) very different; nor do they appear to have had any common plan of working, but to have carried on their investigations in a manner quite independent of each other, and often even with different objects in view.

The result of the American dredgings (for 1869) was to shew that there are 4 different levels of the sea-bottom in the straits between Florida and Cuba or the Bahamas, the first and second of which are comparatively shallow, the third and fourth deeper, and forming the proper floor of the Gulf Stream.

The first of these goes to a depth of 10 fathoms, and has a rich fauna, quite different from the deeper ones; this is the area of the reef-building corals, all of large size, and it extends sometimes to 15 and 20 miles from the shore, and the second has a depth of from 20 to 40 fathoms, with a more scanty fauna. Its bottom is a muddy mass of dead and broken shells, broken corals, and coarse coral sand; its living organisms are worms, and such mollusks as prefer this kind of bottom; with a good many algæ. The dead mollusks and zoophytes are chiefly brought by tides and currents, not originally belonging to the zone. The third zone is a broad slanting table-land, from 50 or 60 to 200 or 250 fathoms deep, beyond which the sea-bottom sinks abruptly. It is from 8 to 10 and even 20 miles wide; it has a rocky floor, composed of a coralline limestone conglomerate, wholly built up of and by the organisms now inhabiting it (and reminding us very much in its appearance of the coral rag), which organisms are constantly increasing its thickness. Its fauna is extremely rich, both in species and individuals; there are small corals, of quite new genera, whose general affinity is with the tertiary and cretaceous types, and very many echinoderms of small size, also most akin to the Cretaceous types. Salenoid and Discoidea-like forms never known before among living Echini.

Most of the mollusks, too, are new; one, *Voluta Junonia* (not new, but very rare before, and probably always derived from this plateau), is akin (closely) to a crag, and also to a Miocene shell: two Brachiopoda, *Terebratula Cubensis*, (Pourtales), and *Waldheimia Floridana* are very common, and contribute greatly to give this fauna an antique character; worms, also, and Crustacea (new) abound, and some new fishes. Algæ are much rarer, but smaller sponges thrive among them, including a small Hyalonema.

The fourth zone sinks rapidly from the last to 400 and 500 fathoms, and even to 800 and more, forming the proper lower floor of the Gulf Stream, and composed everywhere of thick adhesive mud, with a much less rich fauna than the last. The cause of this is probably its being muddy, not rocky; for it has many inhabitants among animals which like such a bottom. This mud does not seem to be at all due to the turbid waters from the Amazon and Orinoco, although the Gulf Stream sweeps past their mouths.

Three Echinoderms at least of this zone are of Cretaceous types.

Carpenter's researches were carried on in the deep sea, at nearly unvarying depths, from 500 to 600 fathoms. One great difference from Agassiz's investigations was that he found cold currents at the same depth, running by the side of the warm ones, or at least not very far off; and his attention seems to have been much directed to the differences caused by these two different currents, and to their different temperatures. Their direction was, of course, also quite different; one from N. (or thereabouts), the other the Gulf Stream proper. This latter had a bottom chiefly composed of the Globigerina mud; the former of stones and sand, probably derived from Iceland or Labrador. The temperature of the warmer current was generally 52°, min. temperature, 47°; min. temperature of the colder one was 32° and 34°, both taken at the same depth. The fauna of the warmer was far more abundant, and its type, though not exclusively so, that of the warmer temperate seas. The fauna of the colder area was much more scanty, and in great measure of a true Boreal type. These two faunas were found within 50 miles of each other. Within this cold area was found a shallow bank, only 170 fathoms deep, and with a temperature of 41°.7, and a fauna clearly intermediate between the others. The fauna of the chalk-like deposit now in progress over the warm area (found, also, in lat. 61°, at a depth of 650 fathoms,) is interesting from its relationship to the true Cretaceous fauna. Silicious sponges are abundant, some corresponding so closely in structure to the Ventriculites of the chalk that they must be identical; also Xanthidia were found, microscopic organisms common in sections of flint; two Brachiopods, *Terebratulina cap. serpentis,* quite identified with a Cretaceous species; and *Waldheimia cranium* at least representing another Cretaceous type. Of Echinoderms, a Rhizocrinus, *R. Lofotensis,* (Sars) also found on the Floridan coast (with two other crinoids), and on the coast of Norway, and on the Josephine Bank, between Portugal and the Azores. The Rhizocrinus carries us back to the Apiocrinite tribe of the Oolitic period, which had hitherto been supposed to have had its last representative in the Bourgetticrinus of the chalk, to which this Rhizocrinus bears on some points a remarkable correspondence; also of zoophytes, a living Oculina found here seems generically allied to a Cretaceous type.

On the neighbourhood of these two areas—cold and warm—Carpenter observes that two deposits may be taking place within a few miles of one another, at the same depth and on the same geological horizon (the area of one interpenetrating the area of the other), of which the mineral character and the fauna are both different, this difference being due, with regard to their mineral character, to the direction of the current which has furnished their materials, and also to the temperature of the water brought by that current. So that if the cold area were to be raised above the surface, and the deposit now in progress at the bottom to become dry land, some geologist in future might find this to consist of a barren sandstone, including fragments of older rocks, whose scanty fauna would for the most part bear a boreal character; whilst if a portion of the warm area were elevated at the same time, the geologist would be perplexed by the stratigraphical continuity with the former of a cretaceous formation, produced by microscopic and very humble organisms, under the influence of an elevated temperature, and including a vast number of sponges and other animal remains, many of them belonging to the warmer temperate regions; and he would naturally suppose these widely-different climatic conditions to have prevailed at different periods, which yet are proved to exist simultaneously at corresponding depths over wide contiguous areas of the sea-bottom, in virtue solely of one area being traversed by an equatorial, and the other by a polar current. Further, in the midst of the cold area our geologist would find a hill 1,800 feet high, covered with a sandstone, continuous with that of the land from which it rises, but rich in the remains of animals belonging to a more temperate province; and he might easily fall into the mistake of supposing that such different faunæ occurring at different levels must indicate two distinct climates, separated in time. So also, more generally, we may see how changes may take place in the marine fauna of any particular area (as we know has often happened in former periods), without any corresponding changes in its general condition; for deep seas must always have existed, and therefore also varieties in submarine climate as great (at least) as now, depending on Equatorial and Polar currents, which must always have been flowing. Hence, also, since changes in the direction of such opposing currents must have been produced by any upward or downward movement of the sea-bottom, a considerable modification, or even a complete reversal of the submarine climates of adjacent areas may have followed on alterations in the contour of the land, or in the level of the sea-bottom at a great distance, perhaps 1,000 miles off.

Such a case was probably the elevation of the Andes range, and the closing thereby of the Isthmus of Panama. Till that took place, while the isthmus was open, the Atlantic equatorial current must have been continuous with the Pacific ditto; and there is Palæontological and other evidence that this channel was open during the Cretaceous period. So that we may assume that the Gulf Stream has taken its backward easterly course since that period; though even before that there would have been a great Atlantic current flowing from N.E. to S.W. The resemblance of this deep-sea fauna to the Cretaceous fauna (which is expected to be still farther confirmed) would go far to prove what seems generally very probable, that the deposit of Globigerina mud has been going on over some part or other of the North Atlantic sea-bed from the Cretaceous epoch to the present time; this mud being not merely *a* chalk formation, but a a continuation of *the* chalk formation.

Professor Wyville Thomson has observed that the oscillations of the earth's crust in the northern part of the Northern Hemisphere do not seem to have exceeded 1,000 feet since the beginning of the Tertiary epoch, and Agassiz says on the American side not more than 600 or 700 feet; so that a vast area of the North Atlantic must always have been submerged through the Tertiary and Quaternary periods. Of Echinoderms there are 18 species of identical genera on both sides, out of 23 (in all) on the Pacific side; of Ophiuridæ 12 species on each side, closely related to each other, and of these several are but varieties; also one-third of the fishes on the two sides are quite identica . All writers agree that up to the Cretaceous period the equatorial current was unbroken, passing through Central Asia, Arabia, the north part of Africa, and a narrow strait at Panama, and sending branches north and south along the eastern sides of the great continents. Deep-sea species would be the first to be cut off and isolated by any rise of the land in the course of any current, as at Panama, and so to remain as outliers, mementoes of a former condition of currents, or even of a previous geological period; and thus the deeper we go, the farther back in time will be the representation of species in one sea by those in another.

Agassiz also infers from his examination of the deep-sea bottom, that *none* of our stratified rocks have been formed in very deep waters; and, *if* this be so, it would follow that our present continents, as circumscribed by the 200 fathom curve or thereabouts, and the oceans below that depth, have always retained their relative outline and position; the continents having always been areas of gradual upheaval, with relatively slight oscillations of rise and subsidence, and the oceans always areas of gradual depression, with equally slight oscillations.

He thinks the evidence clear all through North America, on the east side of the Rocky Mountains, that there has never been any great subsidence since the oldest formations rose above the waters; and though parts of it have certainly been recently submerged to 600 or 700 feet, yet that is included in the limits of the 200 fathom curve round the present shores.

Again, he thinks that loose materials spread on the surface of the earth (such as drift, &c.,) are *not* due to oceanic currents; for, firstly, no trace is found in the trough of the Gulf Stream of the characteristic mud which flows out from the mouth of the Amazon river in such quantities as to discolour the ocean for a great distance from the shore, though this equatorial current of the Atlantic is one of the most powerful currents known, and sweeps along by the mouths of the Amazon and Orinoco; and, secondly, from the experience now gained in deep-sea dredging, where marine organisms are found at all depths, and often in very great profusion (microscopic ones, if not larger, teem in bottom mud and sand), we are not justified in considering extensive deposits of loose materials as marine in which no marine remains are found. Through all the western prairies of North America he found no sign of marine animals or plants, and, he thinks, no evidence of their marine origin, or of the influence of oceanic currents in distributing the loose materials scattered over them; while he did find the foundation rock, on which these loose materials rest, everywhere polished, grooved, and scratched, as all glaciated surfaces are.

THE SECTIONS OF STRATA EXPOSED ON THE HUYTON AND ST. HELENS BRANCH RAILWAY.*

By Charles Ricketts, M.D., F.G.S.

During the construction of the Huyton, Prescot, and St. Helens Branch Railway, now approaching completion, several interesting sections have been exposed at different

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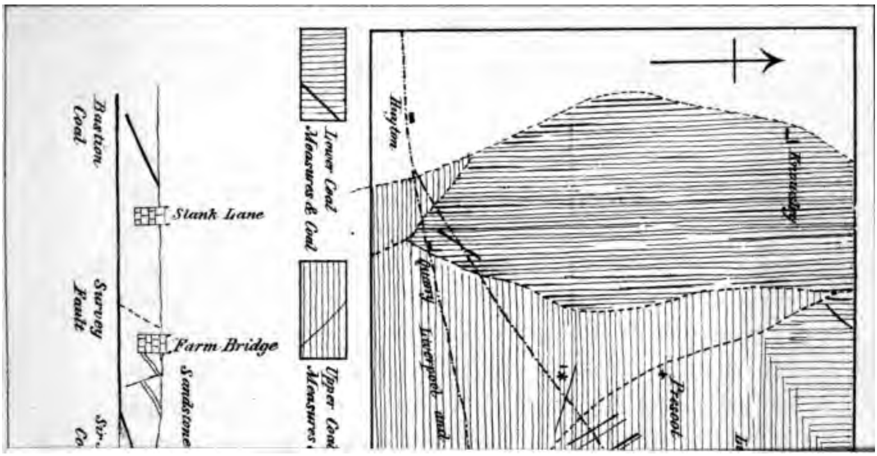
* A detailed description of the district is given in Memoirs of the Geological Survey; "The Geology of the Country around Prescot," by Edward Hull, A.B., F.G.S.



ERRATA.

Page 57—line 7, for "to remain" read "extending;" page 60—line 29, for "heading" read "hading;" page 61—line 23, for "to remain" read "they;" page 62—line 27, *dele* "caused;" page 63—line 8, for "*Calamities*" read "*Calamites;*" page 63—line 17, for "*Spirobis carbonarinus*" read "*Spirorbus carbonarius.*"

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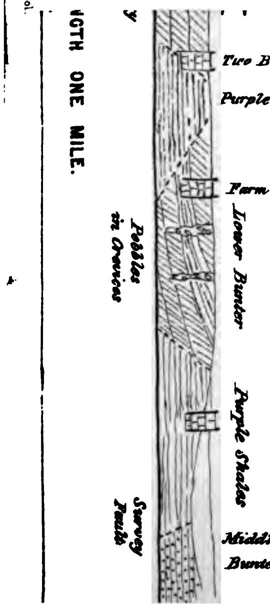

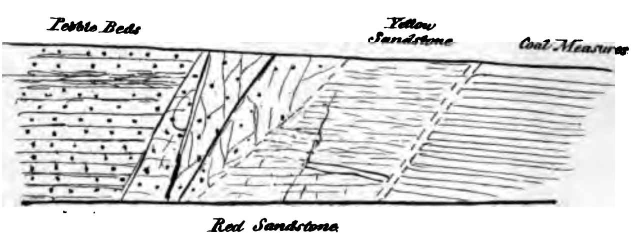

SECTION 2. THATTO HEATH FAULT

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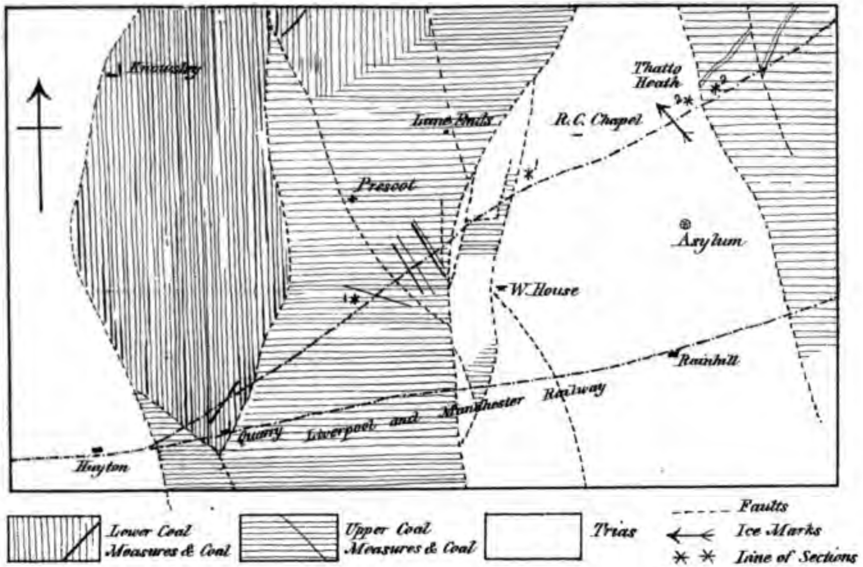

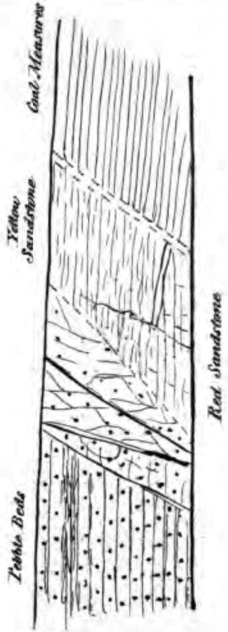

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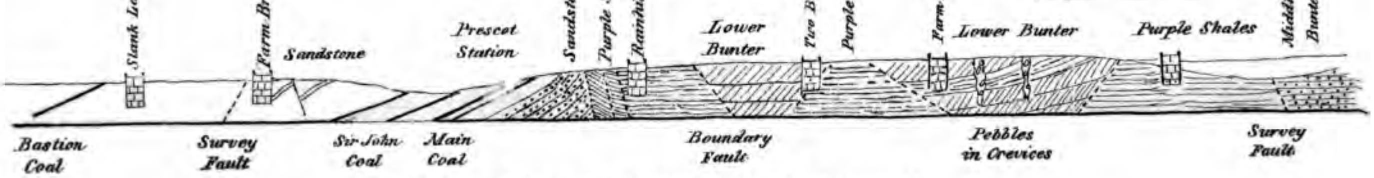

SECTION 1. SOUTH OF PRESCOT, LENGTH ONE MILE.

places along the line; and though, previous to examination, a considerable portion of the cuttings had been obscured by soil being spread over them, the more important and interesting features were, in the early part of the year, beautifully displayed, confirming the general accuracy of the maps of this district which have been constructed by the Geological Survey, and to remain our knowledge of geological facts, which in a country so covered as this is with Glacial Drift could not otherwise have been determined.

Lower or Gannister Measures.—The first exposure occurs in a cutting a little north of Huyton Quarry, where a series of beds, situated somewhat lower in the Gannister or Lower Coal Measures than those of the quarry, were passed through; they are seen on the north side of the railway for a distance of one hundred yards, to as far as the farm bridge, and in the places left for its abutments, dipping at an angle of 12° or 14° to S. 35° E., being very nearly in the same direction as the strata in Huyton Quarry. The succession of the beds in descending order is—

1.—Soft shale, thickness undetermined.	
2.—Coal	1 foot 6 inches.
3.—Clays and shale, in some places concretionary	10 feet.
4.—Black shales, with partings of thin beds of sandstone	17 „
5.—Beds of sandstone, with partings of black sandy and micaceous shale	20 „
6.—White sandstone, having a saccharoid fracture	13 „

7.—Soft yellow and ferruginous sandstone, current-bedded, and thinning out rapidly, about	2	„
8.—Sandstone	5	„
9.—Dark micaceous sandy shale, with sandstone nodules.		

The nodules situated amongst the uppermost of these beds of shale (9) are of a disk-shape, convex below and flattened on the top, and are not concretionary. From their stratified appearance upon being fractured, it would be inferred that they have been formed by a deposit of sand, which has filled up basin-shaped hollows in the shale.

The coal (2) is exposed at its outcrop, and, where the south abutment of the bridge is situated, forms the uppermost bed. A bed of coal situated in strata somewhat similar to those displayed in this section was formerly worked at Knowsley, and is referred by Mr. Hull to the "Mountain Mines Coal."*

Upper Coal Measures.—From the cutting near Huyton Quarry the railway crosses the valley upon a lofty embankment for three-quarters of a mile, when, south of Prescot, it enters a cutting, the sides of which had been covered over as far as the second bridge; but a careful search disclosed the "Bastions Coal" between 90 and 100 yards from the first or Stank Lane Bridge (section No. 1), *i.e.*, in the position marked upon the six-inch survey map.

Upon the other side of the bridge the cutting is continued for about 140 yards through white sandstone, in which there is evidence of some amount of disturbance, shown by contortions in the thin beds of shale which for 40 yards intervene between the beds, caused probably by close approximation to a fault marked as extending past Prescot to the boundary fault, but the exact situation of which has not yet been determined. At the termination of the cutting, the underlying strata having become shaly, a greater amount of denudation has taken place, so that their edges form the surface-level of the railway. The "Sir John Coal," and another situated above it, called "Little Delf"* on the six-inch survey map, are seen amongst these shales in the watercourse on the south side of the railway, appearing as "smut," being situated about 100 yards to the eastward of the places given on the survey map, from information, as the site of their outcrop. These coal-beds are not only seen in the watercourse, but were likewise proved on the oppposite side of the line.

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* Hull, "Geology of the Country around Prescot," p. 8.

Passing the Sir John Coal a succession of sandstones and shales are seen upon the south side, as far as the intended site of the Prescot station, where the "Prescot Main Coal" is cut across. This consists of two beds, the uppermost or thick coal being 10 feet thick, with a parting of one foot of shale intervening and dividing it into two nearly equal portions, and the thin coal, about two feet thick, situated 30 feet below the former, and separated from it by black and grey shales. The excavations which have been made for the station exposed old workings in the thick coal, by the side of a fault, which has caused a displacement of three feet in the thick coal. The thin coal is underlaid by shale and sandstone to about 60 yards from the Rainhill Road, where the strata are broken off by a fault which crosses the railway in a north and south direction, and has thrown down against them upper beds of the Coal-measures. These upper strata, as far as what is considered to be the Boundary Fault of the Prescot Coalfield, consist of purple and mottled sandstones, shales, and clays, and present a striking contrast to the white sandstone beds against which they rest, but are separated from them by an interval of nine or ten feet, which is filled with a grey clay and occasional blocks of Coal-measure sandstone.

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* The name of Little Delf is also applied to the lowest bed of coal in the Prescot district.

The railway crosses the strike of the beds as far as the fault, almost at right angles, the strata dipping towards the West at about 12° or 15°, excepting in the immediate neighbourhood of the fault, when they are raised to 30° and 40°, dipping towards S. 65° W. But upon the other side of the fault the direction is reversed to N. 85° E. at 45°, at which angle it continues for twenty-eight yards, when another fault changes the dip to N. 20° E. at 15°, to be again altered after twelve yards by a third fault, which causes a displacement in the beds apparently of ten feet, bringing them to a horizontal position, which is retained as far as the Boundary Fault, where the coarse and current-bedded sandstones of the Lower Bunter of the Trias rest against these purple Coal-measure strata.

As the formation of the Liverpool and Manchester Railway exposed the presence of a small area of Coal-measures to the south of Royal Oak Farm, Whiston, which would otherwise have been unknown,* so, likewise, have the excavations for this railway displayed two patches of strata, similar to those on each side of the Rainhill Road, having intervening beds of Lower Bunter Sandstone, which have been thrown down by faults. The first fault can be seen beneath the northern arch of the bridge by which Two Butt Lane crosses the railway, its direction being similar to that of the Survey Boundary Fault, but heading to the West. After a short interval of horizontal Coal-measure strata, there occurs, at a distance of 50 or 60 yards from a farm (Chorley Hall) bridge, a nearly east and west fault, not yet covered over, throwing down the Bunter to the north. This Triassic Sandstone, which is not covered with Glacial drift, is similar to that first met with, but is fissured in many places without much displacement, the interstices being filled with subangular and rounded pebbles from the Coal-measures and Triassic Sandstone, as well as "liver-coloured" and quartz pebbles derived from the Pebble-beds or Middle Bunter. There have likewise been found a few specimens, consisting of Granite, Porphyry, and Greenstone, one of which affords an excellent example of ice-markings, and also a flint pebble; the minor fractures and intervals, caused by the beds having been somewhat separated from each other, are closed by a dark sandy clay. The existence in the fissures of pebbles, some of which are characteristic of the Boulder-clay in the neighbourhood, would lead to the inference that the occurrence of the fracture must be attributed to a recent, or, at least, a Post-glacial period.

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* Hull, p. 13.

One hundred and ten yards before arriving at the lane leading from Holt Lane to Four Lane Ends, Eccleston, another north and south fault occurs, again bringing in the Coal-measure strata which have been proved to extend to one hundred yards beyond the bridge but to remain must very shortly be cut off by a fault, as the Trias was seen coming to the surface immediately afterwards.

Pebble Beds and Thatto Heath Fault.—The cutting is continued for about half the distance to Scholes Farm, the New Red Sandstone appearing at intervals above the level of the railway,* covered with beds of Glacial Drift, viz., the Lower Drift Sand† of Mr. Morton, containing a few broken and water-worn marine shells, and the Boulder-clay which surmounts it. For the remainder of the distance the railway runs along upon a level with the surface, and then passes through a cutting, which for half a mile is 40 to 50 feet deep, and displays the Pebble Bed Sandstone in great perfection.

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* This portion of the section was covered with soil previous to the second visit.

† "Geology of the Country around Liverpool," by G. H. Morton, F.G.S., p. 42.

Mr. Hull has described these Pebble-beds as "composed of reddish-brown sandstones, of a more compact nature than those of the Lower Mottled Sandstone, and as containing rounded pebbles of quartz, generally of a purple and grey colour, which have not yet been identified with any known English rock;" but at the meeting of the British Association at Exeter he pointed out the exact identity of these "liver-coloured" quartzites with those of the Old Red Sandstone Conglomerate of Dunbartonshire.

At the termination of the deeper portion of this cutting the Thatto Heath Fault (section No. 2) is well exposed, the Pebble Beds being thrown down to the westward of the red, sandy, and micaceous shales of the Coal-measures, having, intervening, a step fault, the lowest beds of the interposed strata exposed at and a little above the level of the railway, are of a dark-red and soft sandstone, separated by an irregular surface from a soft yellow sandstone, which surmounts them. The fault forms an interval of seven or eight feet between the Coal-measure strata and the Bunter Sandstone, which is filled up with disintegrated purple shales and clay, and, to the west side of the fault caused a considerable amount of fracture has taken place in the Pebble Beds.

Beyond the Thatto Heath Fault the cutting continues for more than half a mile through the coal-measures of the St. Helens district, displaying for a short distance the existence of many slight displacements of the strata, and as it approaches the fault which runs in a north and south direction from St. Helens to Sutton

Heath, exposes a bed of coal (St. Helens four foot coal?) along its outcrop, where it is covered with Boulder-clay, and also the "Ravenhead Higher and Main Coal," which latter is cut off by the fault at its upthrow, in the situation as marked upon the map.

A little below the Main Coal the remains of trees were standing *in situ*, and numerous specimens of the stems, leaves, and fruits of *Calamities* and of *Lepidodendron* Ferns, &c., also a beautifully preserved wing of an Orthopterous insect, have been collected from this locality by the Rev. H. H. Higgins, and have been presented by him to the Liverpool Museum.

The extension of the cutting displays the whole series of beds from the Ravenhead Coal to somewhat higher than the Pigeon House Coal, immediately above which have been found more than 15 species of *Conchifera*, amongst them *Anthracoptera Browniana*, Salter, with *Spirobis carbonarinus*, remains of Crustaceans, &c.

Glacial Markings.—At the deep cutting in the Pebble Beds near Scholes Farm, wherever the surface of the rock is covered with the sands and clays of the Glacial period, it remains beautifully planed, grooved, and striated; occasionally a quartz pebble is seen, worn and roughened on its exposed surface; also small indentations, which may have been the impression of pebbles, having passing from them in a N.W. direction, grooves deeper and larger than the others, showing that the moving power which has produced them had taken a course from the S.E. to N.W.

The surfaces of the sandstone rocks in many places in the neighbourhood of Liverpool have, upon the removal of the Boulder-clay, been discovered by Mr. Morton* and others to be covered with grooves and striæ, in a similar manner to those in these Pebble Beds.

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* "On Glacial Surface Markings on the Sandstone near Liverpool," by G. H. Morton. Quarterly Journal Geological Society, vol. 18, p. 377.

The preservation of these markings, under the covering of Glacial drift, leads to the inference that this locality must, at the time of their formation, have been situated somewhat below the sea-level, and that inland the surface was overlaid by a thick expanse of ice, which, extending to some distance seaward, formed barriers as in Greenland, &c., at the present time; otherwise these marks could not, upon the removal of their glacial covering, have escaped obliteration, from the action of either marine or atmospheric agencies.

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SESSION THE TWELFTH,

1870—71.

(The Authors having revised their own papers, are alone responsible for the facts and opinions expressed in them.)

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LIVERPOOL GEOLOGICAL SOCIETY.

SESSION TWELFTH.

OCTOBER 18TH, 1870.

Anniversary Address by the President, **George H. Morton**, F.G.S., F.R.G.S.I.

Gentlemen,

In concluding my Address last year, I directed your attention to the approaching meeting of the British Association in Liverpool, and to the necessity of individual exertion to promote its success. Although few local papers were read before the Geological Section I think that the success of the meeting was in some degree influenced by the exertions of several of our members, and doubtless our Society will be rewarded by the increased impetus given to scientific enquiry which always pervades a community that has had the advantage of entertaining the Association.

My former Address was an essay on "The Progress of Geological Research in connection with the Geology of the Country around Liverpool," though it was incomplete in the absence of any reference to the Triassic strata. This missing link in our local geology I now intend to supply. The mapping of the strata under the south of the town has long been a task of difficulty, but which has been partially removed by recent excavations in Toxteth Park. The sections that were opened will enable me to speak with greater confidence regarding the Keuper strata in that locality than I could have done twelve months ago.

Before, however, proceeding with my principal subject, I intend, in order to preserve the unity and intimate connection between the Addresses of two Sessions, beginning with some supplementary remarks relating to the Carboniferous, and ending with the most Recent strata, though on those subjects I have little to add. I have endeavoured to include the title of every paper and other contribution that has been published relating to the Geology of the Country around Liverpool, including the Mountain Limestone of Flintshire. The quotations which illustrate the list are frequently given to show the opinions held by local observers at the time they were written. Many are descriptive of phenomena which were singularly misinterpreted, and fallacies it is unnecessary to explain or correct. You will have no difficulty in observing where progress has been made.

In reviewing the state of geological knowledge in former years, do not imagine that I have any desire to disparage the labours of our predecessors or the conclusions that they gathered by patient observation. The geology of to-day is widely different to that of the last generation. Since then the literature of the science has become enormous, while the multiplicity of observations recorded, and the means of overcoming difficulties by special training are so great, that we must only look back to early geological conclusions with a kind of historical interest. The pioneers of our science were few in number and they had great difficulties to contend against. Facts and experience had to be collected only by years of patient and laborious observation. Fruitless journeys had to be made, and mistakes published before they could be corrected, yet all these were steps in advance which prepared the way for those who were to follow.

CARBONIFEROUS STRATA.

During the past year the following additional communications have been added to the list of contributions relating to the Carboniferous strata near Liverpool, and they were all read at the last meeting of the British Association.

"The Mountain Limestone of Flintshire and part of Denbighshire." By G. H. Morton, F.G.S.

"Remarks on the Fossils from the Railway Section at Huyton." By W. Carruthers, F.L.S.

"Section of Strata between Huyton and St. Helens." By C. Ricketts, M.D., F.G.S. The latter paper is published in the Proceedings of our Society for 1869-70. The others have not yet appeared, but abstracts will be printed in the Report of the British Association for 1870. Considerable interest is attached to the section described by Dr. Ricketts, for it exhibits the Coal-measures faulted against the Trias in several places. Faults showing the dislocation between these formations have seldom been seen in this neighbourhood, and perhaps never were so well exposed as in the railway cutting described. The Coal-measures consist of purple shales and sandstones similar to those discovered some years ago in Sefton Park, by Professor Hull, F.R.S., but it is uncertain as to the position they occupy in the series.

The number of Carboniferous fossils that have been found in this district is now very considerable. When the list of species is made out, the richness of the fauna and flora will be found to be extraordinary. Upwards of 120 species have now been collected and named from the Flintshire Mountain Limestone. Many of them are rare and interesting forms, while the luxuriant growth of the littoral corals in the neighbourhood of Mold is probably unsurpassed by any other locality in the kingdom; but I will not anticipate information which will come before you during this or the following Session.

We are indebted to the Rev. H. H. Higgins for the discovery and preservation of the extensive series of fossil plants, mollusca, and fish-remains recently found at Thatto Heath. In addition to fine examples of well-known forms, there are others belonging to rare genera and species. Some specimens are very remarkable as showing fructification; others as enabling palæophytologists to reconstruct old-established genera, and to effect such a reformation as to bring these interesting plants within the domains of structural botany. Perhaps the most important specimens collected were two wings of a Neuropterous insect. Unfortunately the largest of these was found by a non-resident in Liverpool. The identifying and cataloguing of the Collection will no doubt require considerable time and study. Arrangements are now in progress for the publishing of a monograph containing descriptions and figures of the specimens—information I feel sure you will be well pleased to learn.*

TRIASSIC STRATA.

Liverpool has always possessed an abundant supply of building stone. There have been many quarries in the Keuper Sandstone along the eastern side of the town that have been long filled up and houses erected over them. Quarries have been worked in Park Road, Mill Street, Great George Street, between Rodney Street and Hope Street, Great Newton Street, Islington, Byrom Street, and Rose Place. At all these places the Keuper Sandstone was obtained, and the oldest public buildings in the town were constructed of it. An immense quantity of stone was obtained from a large quarry which was afterwards converted into St. James's Cemetery. In 1773, during the working of that quarry, a spring was discovered, and Dr. Houlstone published a pamphlet on its properties and effects. It is the same spring that still yields a supply of water. Thirty years ago a large quarry was worked on the south side of Washington Street, and the fine monolithic columns in front of Great George Street Chapel were obtained there, as well as the rest of the stone used in the construction of the building. The footprints of the Rhynchosaurus were found there in great abundance by Mr. Alfred Higginson, M.R.C.S.*

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* The collection has been deposited in the Liverpool Free Museum, and is therefore accessible to students.

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* Doubts having been expressed as to the former existence of this quarry, the following letters are inserted:—

44, Upper Parliament Street,
March 13, 1871.

Dear Mr. Morton,

In reply to your note, I do remember well the deep and interesting stone quarry in Rathbone Street; it was entered from that street and *lay behind it and Washington Street, Sands Street South, and St. James's Road*, not actually coming up to any one of them. I recollect seeing *some*, if not *all*, of the pillars for Dr. Raffles's new chapel cut there. I was surprised to see such yellow stone become so much whiter in process of being worked. An extra column was cut in the rough in case of accident, but was not needed; it lay for a long time, and was then broken up. My impression is that no stone was used from that quarry for the chapel except for the pillars. There were two sets of footmarks found—those in a reddish marly stratum, small and such as you allude to, and others, deeper down, of the Cheirotherium (*i.e.*, Labyrinthodon) very small compared with the Storeton prints. The date of quarrying the pillars would be 1840-41. The well-known Tomkinson, sen., worked the quarry, I believe. I have no doubt Mr. Picton will vouch for much of

I have not been able to find any reference to the sandstone strata of this neighbourhood prior to the year 1838. The early papers of the Literary and Philosophical Society do not include any relating to local geology. Previous to 1844 there was a Natural History Society in Liverpool, but no account of its proceedings was published. That the society included geological observers is obvious, for the first paper † to any scientific society relating to the Triassic

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what I have said, and if needful the minute book of the old Natural History Society (now in possession of the Literary and Philosophical Society) might furnish some particulars.

Believe me, dear Morton, truly yours,
ALFRED HIGGINSON.

26, Rock Park, Rock Ferry, Cheshire,
13th March, 1871.

To the Secretary of the Liverpool Geological Society.

Dear Sir,

In answer to the question put to me at the last meeting of the Society concerning the locality from which the columns in front of the chapel in Great George Street were obtained I submit the following statement, made to me by Ezekiel Thompson, one of our foremen stone masons, who resides at 36a Back Salisbury Street:—

"There were two stone quarries in Rathbone Street, about midway between Duke Street and the St. James's Market, when the chapel in question was built. One of the quarries was worked by the late Mr. John Tomkinson, and the other by the late Mr. Leatham. The stonework of the chapel was executed by the late Mr. Tomkinson, who obtained the *whole of the stone used in the structure, including the columns, from the quarry in Rathbone Street.* I worked in the quarry at the time the columns were got.

"They were cut in the usual way, transversely off the beds in one piece, and then conveyed upon two stone-trucks, each having two wheels, from the quarry to the chapel, where they were dressed ready for setting. The trucks were let down the decline from the quarry to Great George Street by a rope, one end of which was held in the quarry and the other end attached to the trucks, then they were drawn by horses to the chapel.

"The quarries were worked from Rathbone Street up towards St. James's Road, and the head of the stone in the quarry was at least fifty feet as it was worked."

I am, yours truly,
ISAAC ROBERTS, F.G.S.

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† Proceedings, Geological Society, vol. 3, p. 12.

strata of Liverpool was "An Account of Footsteps of the "Cheirotherium and other unknown animals lately discovered in the Quarries of Storeton Hill, in the Peninsula "of Wirral, between the Mersey and Dee, communicated "by the Natural History Society of Liverpool, and illus-"trated by drawings by Mr. John Cunningham." The paper states that the footprints were discovered in June, 1837; and that the circumstance having been made known to the society, a committee was appointed, who drew up the report, which states:—

"The casts of the Cheirotherium, although the most "remarkable, are by no means the most numerous which "exist on the Storeton sandstones. Many slabs are crowded "with casts in relievo, some of which are supposed to have "been derived from the feet of Saurian reptiles, and others "from those of tortoises. Occasionally the webs between "the toes can be distinctly traced. It is impossible to look "at the slabs and not conclude that the clay-beds on which "they rested must have been traversed by multitudes of "animals, and in every variety of direction."

"The peninsula of Wirral" is described as consisting of New Red Sandstone; "and towards the northern "extremity the formation may be separated into three "principal divisions. The lowest is composed of beds, "slightly inclined towards the east, of red or variegated "sandstone, occasionally abounding with pebbles partly "derived from the Coal-measures; and in the bottom strata "either angular or little water-worn. Seams of marl are "very rare in this division, the argillaceous matter being "confined to nodules or concretions of clay of the same "colour as the sandstone.

"The middle division consists of white or yellow "sandstone, in some places argillaceous, and frequently "containing round concretions of clay and pebbles. The "strata are separated by seams of white or mottled clay, "occasionally almost imperceptible, but sometimes several "inches thick.

"The uppermost division is formed of red or variegated "sandstone, enclosing also nodules of clay and pebbles of "quartz; and it abounds with strata of red marl.

"The Storeton quarries are situated in the middle "division; and the casts which have hitherto been noticed "occurred on the under surface of three beds of sandstone, "about two feet thick each. . . . . The authors of "the report are of opinion that each of the thin seams of "clay in which the sandstone casts were moulded formed "successively a dry surface, over which the Cheirotherium "and other animals walked, leaving impressions of their "footsteps; and that each layer was submerged by a "depression of the surface. The lowest seam of clay was "so thin, that the marks penetrated into the subjacent "sandstone."

It is very evident that the order of succession of the New Red Sandstone here given was not a hastily written report to accompany the account of the footprints; for the lithological descriptions of the strata are remarkably accurate, and without a knowledge of the great faults which run north and south, the succession would *seem* to be correct.

The next paper was one entitled "An Account of Impressions and Casts of Drops of Rain, discovered in the Quarries of Storeton Hill, Cheshire." By John Cunningham, F.G.S.* Mr. Cunningham was the first to assign the origin of the circular pits that occur in the upper surface of beds of clay to the effects of rain. He also described the casts of them on the under side of the overlying sandstone. Another paper by the same author was read before the Geological Society in May, 1846, "On some Footmarks and other Impressions observed in the New Red Sandstone Quarries of Storeton, near Liverpool." This communication referred to the supposed discovery of Ornithichnites in the Storeton quarries.

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* "Proceedings, Geological Society," vol. 3, p. 99.

In the Proceedings of the Literary and Philosophical Society of Liverpool the first notice of the New Red Sandstone was the exhibition of a "Section of the Strata from Flintshire to Huyton inclusive." The section was published in the "Proceedings of the Society, May, 1845," vol. 1, and it shows the succession of Lower Red, Middle Yellow, and Upper Red Sandstone.

From the Proceedings of the same Society it appears that the following notices and papers were brought forward at various periods :—

"Mr. Cunningham exhibited an impression from Store- "ton Quarry, which he considered to be that of a large "Tortoise." November, 1845.

"Notes of an Oral Lecture, delivered on Geological "subjects, during a recent Excursion to Storeton." By Dr. Hume. May, 1846.

"Mr. J. B. Yates exhibited to the Society a Geological "specimen, apparently part of the stem of a plant, found "in the New Red Sandstone rock, in the course of the "excavations which are now being made in Grafton Street." November, 1846.

"Mr. Cunningham exhibited the remains of vegetables "found in the New Red Sandstone at Toxteth Park, in "the excavations taking place there, supposed to be speci- "mens of Lepidodendron." November, 1846.

"Mr. Cunningham read the following paper :—

" On the Geological Conformation of the Neighbour- "hood of Liverpool, as respects the Supply of Water." December, 1846.

"Mr. Cunningham exhibited a plan, and explained "the phenomena of a fault fracture, and lines of stratification in a portion of the New Red Sandstone, shown in "a section of the excavations for the foundation of the "new Concert Hall of the Philharmonic Society, in Myrtle "Street and Hope Street." March, 1847.

"Mr. Cunningham exhibited a specimen of what he "considered was the impression of a Medusa, from Storeton "Hill." November, 1847.

"Mr. Cunningham exhibited a cast of some impressions found on a stone taken from the west side of "Storeton Hill; the original could not be procured. At "one part there were impressions of two feet, each consisting of a sort of boss or heel with three long slender "toes, probably webbed; at another, were impressions of a "foot with three short toes, but without a heel; at another, "there are marks which led to the belief that the foot had "been cased in a shell; at another, an impression left, it "was supposed, by a medusa. (Lithographic copies were "ordered to be prepared, and they will be found at the end "of the volume.)" February, 1848."

The "Flora of Liverpool," by Dr. Dickenson, F.L.S., was published in 1851. It contains an introductory chapter "On the Physical Geography of Liverpool and Wirral," which describes the geology of the district. The New Red Sandstone around Liverpool is said to consist of the Keuper and Bunter Sandstone, though it does not appear that the formations had been separately identified. The three subdivisions of "Lower Red, Central Yellow or White, and the Upper Red, the whole amounting to a very considerable thickness," being still the accepted arrangement of the strata. It is said that "a number of *trap dykes* may be observed protruding themselves through the sandstone in various parts of the neighbourhood—as at St. Domingo Lane and Mere Lane, at Everton, &c." After alluding to the escarpments of the ranges of hills being with few exceptions towards the west, particular attention is directed to the eastern escarpment of Flaybrick Hill. The anticlinal at Storeton is also mentioned. This introduction to the "Flora of Liverpool" contains a *resumé* of the geology of the district to 1851.*

The second meeting in Liverpool of the British Association was held in 1854, and Mr. Edward Hull, F.G.S., who had just surveyed the district for the Government Geological Survey, read a "Paper explanatory of a Geological Section, extending from the Island of Little Eye across the Peninsula between the Estuaries of the Dee and Mersey to the east of Liverpool." An abstract of the paper is to be found in the British Association Report for 1854. Mr. Hull's paper and the Geological Survey map threw a flood of light on the subdivision and succession of the Triassic strata of the neighbourhood. The Keuper was described as overlying the Bunter formation, and the old idea regarding the succession was heard of no more. I cannot let this opportunity pass without again acknowledging Mr. Hull's kindness to me when I was following up his work sixteen years ago.

In 1856 I read a paper before the Literary and Philosophical Society, "On the Sub-divisions of the New Red Sandstone between the River Dee and the up-throw of the Coal-measures east of Liverpool," and in 1860, another "On the Basement-bed of the Keuper Formation in Wirral and the Southwest of Lancashire."

In 1863, I still further described the Triassic Strata in "The Geology of the Country around Liverpool," published by the Liverpool Naturalists' Field Club.

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* It was probably written by Dr. D. P. Thomson.

These papers include various others that have appeared in the Proceedings of this Society at various times to 1863, and therefore it is unnecessary to mention them.

It is not desirable to introduce newspaper reports of scientific investigations. I must, however, refer to a Lecture on "The Geology and Water Supply of the Hundred of Wirral," by Mr. Cunningham, F.G.S., delivered several years ago in Birkenhead. I have no date attached to the printed slips cut from a local paper at the time, but it may be found somewhere about 1863, or perhaps rather later. In this lecture Mr. Cunningham describes the geology of the district in conformity with the Geological Survey maps and our present classification of the strata, but with regard to the local water supply he does not seem to have altered his views. He says that the Storeton footprints had been exposed to the gaze of the quarrymen and other people for 15 or 20 years before he gave publicity to them in 1837.

This year (1870) the "Geology of the Country between Liverpool and Southport, Geological Survey of England and Wales," by Mr. C. E. de Rance, F.G.S., was published. He describes the Triassic Pebble-beds, Upper Mottled Sandstone, Lower Keuper Sandstone, and Keuper Marls in the district embraced by the map 90 S.E. After referring to several sections, including that at the Hill Farm Quarry, Little Crosby, he says :—

" Occasionally a very hard bed of quartz pebbles occurs
" near the top of the Keuper Sandstone. It is similar in
" physical character to that occurring at the base; and is
" well seen in the Orrell railway section, and in the quarry
" at Waterloo View, where the pebbles run along the
" planes of false-bedding; and it is also seen at Halsall in
" the road and in the brook below the Hall. The pebbles
" are here very plentiful, and are of opaque white quartz."

In the "Geology of the Country around Liverpool," by the same author, in an article in "Nature," No. 46, he states that the Keuper Sandstone is 400 feet thick, and that pseudomorphous crystals of chloride of sodium occur at the top of the sandstones, associated with shale.

Geologists who have directed their attention to the Keuper formation as it occurs in the low range of hills along the N.E. of Wirral will remember its uniform lithological character. The base of the formation is a conglomerate, with white quartz pebbles and fragments or nodules of white and yellowish clay in a coarse sandstone, something like Millstone Grit. The succeeding strata are light gray and yellow sandstones, alternating at irregular distances with beds of shaly clay, often called marl, and sometimes sold as Fullers' Earth. The middle beds are softer sandstones; and higher in the series argillaceous beds succeed, and form the Red Marl. Below the Keuper the Upper Bunter is a soft yellow sandstone without pebbles, nodules, or seams of clay, and below this yellow band, which is about 120 feet thick, the strata assume a variegated or red colour. In illustration of this succession we have at New Brighton, first the "Red Noses," higher in the series the "Yellow Noses," and then the base of the Keuper forming the high ground. Under the centre of Liverpool there is exactly the same order observable. On the Geological Survey map the base of the Keuper is shown to occur along the east of Park Road. The section is well exposed, and presents a coarse conglomerate or breccia, overlying strata of a softer character, and mostly of a red colour. I at one time agreed with Mr. Hull, and considered this conglomerate to be the base of the Keuper; but if I had written on the subject a year ago, I should have called it an interstratified bed in the Pebble-beds. For ten years I have had doubts about these strata at the south end of the town; and in 1863 the sandstones in question were described by me as the "Pebble-beds" and "Lower Soft Red and Variegated Sandstone," cut off from the Keuper by a fault a very little to the north of Hill Street.

During the last year extensive excavations for draining and building purposes have opened sections across the site and land adjoining the "Old Mill" which formerly stood on the east side of Park Road, at the corner of Hill Street, on ground considerably above the road. The sections were principally short cross-cuts and excavations along the strike of the strata—including the supposed basement-bed of the Keuper. In a large square opening for the foundation of a chapel, the beds exposed were the conglomerate-bed, below that soft sandstone; and lower still a bed of shale or clay nine inches thick, the whole dipping to the east and being of a red colour, with some exceptional yellow seams in other contiguous sections. This supposed basement-bed I now consider to be a hard stratum near the top of the Keuper Sandstone — the conclusion being partly drawn from the band of marl below it, though strongly supported by other observations.

There is great difficulty in mapping out a district where the land is covered with buildings, for the chances of examining the strata when artificial openings happen to be made cause a considerable time to elapse before the observations become valuable. Fifty years ago, when the land was open fields, the task would have been an easy one. At that time the area occupied by the Keuper might have been followed by the contour of the ground. Fortunately I have been enabled to derive much information respecting the natural aspect of the Park district as it appeared 40 years ago, when the streets were being laid out, and but few of the houses were built. Mr. Thomas

Duncanson, the Water Engineer of the Corporation, kindly directed me to William Owens, who has lived at the house attached to the Park or Water Street Well for 40 years, and who from the nature of his employment was able to give me some information about the locality. He described the strike of the high ground at St. James's Cemetery as having been formerly connected by a continuous ridge of rock with the eminence upon which the Mill was situated, and says that the streets running east and west were cut through it, and that the ground was levelled as occasion required for building purposes. The sandstone he considers to be of the same kind all along the ridge, but that it gradually changes from a yellow to a red colour from north to south. He also called my attention to sandstone used in the foundation of some houses in Jenner Street, built on the site of the quarry from which the stone was obtained.

The Park Well was sunk in 1828. It is 60 yards deep in red rock, without any indication of bands or fragments of marl. About a third of the distance from the top there is a bed of about a foot in thickness, containing small quartz pebbles, probably the conglomerate described, but the bed of marl previously referred to does not occur in it. Owens also told me that there were, 40 years ago, several large quarries on the west side of Park Road, just in front of the Mill, and between that place and Mill Street. The stone obtained was a red sandstone, and there can be little or no doubt Keuper Sandstone. I remember a similar rock being worked near the top of Mill Street on the east side.

From the sections to which I have referred, and considering the statements of Owens, with the present form of the ground, I have come to the conclusion that the general strike of the Keuper formation as it occurs about St. James's Cemetery is continued southwards, without any cross east and west fault such as I formerly supposed to exist; and that there is no such base of the Keuper on the east of Park Road, as shown on the Geological Survey map, the conglomerate-bed there visible being near the top of the Keuper Sandstone. It is very remarkable that Mr. de Rance should have discovered a conglomerate-bed in a similar position in the country between Liverpool and Southport. The Orrel railway section,* which is about 3,000 feet in length, shows the position of this Upper Keuper conglomerate reposing conformably upon beds of soft yellow sandstone, with white bands at irregular distances. The conglomerate-bed closely resembles that at the base of the Keuper; though all the strata occur in regular order, without any break. The base of the Keuper rests unconformably upon the upper beds of the Bunter Sandstone, as shown in sections at Scarth Hill, near Ormskirk, and at Flaybrick Hill, in Cheshire, and other places.

The only other correction with regard to the local Triassic strata that I have to refer to is, the hade of the two faults (i and j,) plate 1, through Bidston Hill, in the "Geology of the Country around Liverpool." Instead of hading away from each other, they should constitute a trough fault, for the two faults must meet several hundred feet below the surface. The petrological condition is clearly shown in the Flaybrick quarries worked on the strike of the beds, and the Keuper Sandstone which occurs in the well of the Birkenhead Commissioners, the works connected with which are close to one of these faults (i).

The railway line and tunnel from Ranelagh Street to the south of Liverpool will open a section which will permanently settle the position of the strata it will pass through, and, I expect, confirm the conclusion adopted regarding the Toxteth Park beds.

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* The section was exhibited, but has not been published.

COAL UNDER THE TRIASSIC STRATA.

Apart from its geological interest, the Trias is of great economical importance. It not only overlies vast stores of coal, but it yields a copious supply of water, which is so necessary to the health and convenience of a large community.

I have elsewhere stated that the Coal-measures probably occur within 500 feet from the surface in several places in the neighbourhood. The time does not seem to have arrived for an experimental boring being made to test this important conclusion. In making any estimate of the cost of such an undertaking, it is necessary to include the depth between the bottom of the Trias, and the position of the first bed of coal that might happen to underlie the spot where the boring was made—this being an uncertain distance, and probably necessitating a boring to 1,000 feet at the least.

The usual cost of boring is 7s. per fathom for the first 5 fathoms, with an increase of 7s. per fathom for every *succeeding* 5 fathoms. So that while the first fathom would only cost 7s., the last of 200 fathoms would cost 280s., and the total cost of a boring of that depth—1,200 feet—would amount to £1,435, which is however a trifling sum if coal could be actually discovered.

I have brought forward this estimate in the hope that it may tend to prepare the way for proving the long entertained opinion, that the Coal-measures underlie our Triassic strata.

WATER SUPPLY.

I should tire your patience if I were to dilate upon the water-bearing capabilities of the strata around Liverpool. Twenty or twenty-five years ago the local newspapers published a vast amount of discussion on the subject;

though it does not appear that any addition to our geological knowledge resulted from the agitation of the question for a considerable period. Mr. J. Cunningham, in his paper "On the Geological Conformation of the Neighbourhood as respects the Supply of Water," refers to the small quantity of water in the Coal-measures, and says:—"I am inclined to believe that there exists between the New Red Sandstone and the Coal-measures, the lower beds of the division,* composed of clay and sandstone to the thickness of 400 feet. These are impermeable to water." Great importance was also given by Mr. Cunningham to the occurrence of primary north and south faults and the crossing of these by others running east and west, by which he states "the district is broken up into a sort of net-work of fractures and dislocations." He also refers to the infiltration of salt water into the wells nearest to the river, and to the theory that sea water may become purified by percolation through the sandstone strata, and afford an unlimited supply of fresh water. After calculating the drainage-area at 80 square miles, (excluding Cheshire,) and largely increasing the number of wells, he concluded that the probable yield of water that might be available as 12,730,000 gallons daily, and states that "it appears an absolute impossibility to obtain an ample supply adequate to the wants of this large and rapidly increasing community."

Connected with the local Water Supply, and consequently with the Trias, are the following:—

"Reports of the Waterworks Engineer." By THOMAS DUNCAN. July and October, 1866.

"The History of the Flaybrick Waterworks, and Report of the Engineer." By J. F. BATEMAN, C.E., F.R S. August, 1866.

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* Probably meaning the Permian.

In the Abstract of our proceedings for the Session 1865–6, there is a paper of mine "On the Position of the Wells for the Supply of Water in the Neighbourhood of Liverpool," and in the Session 1868–9 there are two valuable papers by members of the Society; one on "The New Red Sandstone as a Source of Water Supply," by Mr. Robert Bostock, and the other "On the Wells and Water of Liverpool," by Mr. Isaac Roberts. These papers are intimately connected by the similarity of the observations they contain, though the conclusions that the authors arrive at are very different. Still they are not exactly antagonistic, except on chemical grounds. Mr. Bostock is of opinion that salt water from the river percolates the sandstone, loses its saltness during the filtering process, unites with some water derived from the surface, and then supplies the wells with fresh water. Mr. Roberts enquires into the source of the water which is so abundantly supplied by the wells, concludes that fresh water is diminishing in quantity, and that the salt water from the river is gradually encroaching through the sandstone and deteriorating the supply.

Mr. Bostock brings forward many arguments to prove, what is almost universally admitted, that the local rainfall is inadequate to account for the supply yielded by the wells. He also endeavours to show that the salt water is converted into fresh water by "a chemical change which takes place when the particles are divided, as they must of necessity be, whilst slowly filtering through sandstone." The paper is full of useful information bearing on the subject he has evidently carefully studied, but with regard to his main conclusion there appear to be chemical difficulties which chemists alone will be able to decide. The principal difficulty, however, is the assumed rapidity with which the salt is precipitated; if we had the greatly extended time, which in other departments of the science is supposed to work such extraordinary results, the theory would be far more readily entertained.

Mr. Roberts commences his paper with the important question—"From what source does the New Red Sandstone in and around Liverpool receive its supply of water?" He and all the other authors I have referred to are unanimously of opinion that the drainage from the rainfall of the district is decidedly insufficient to afford the supply. Indeed, the quantity of well water actually consumed in Liverpool and Birkenhead far exceeds the quantity 12,730,000 gallons* daily, which Mr. Cunningham calculated as the largest probable amount or proportion of the rainfall which ultimately finds its way into the strata, being a ninth part of the mean annual fall. † Mr. Roberts refers to "the expressed views of some members of this society" as "indefinite and somewhat confused in reference to" the source of the water in the sandstone, but I cannot find any statement of the water being conveyed from the hills of Wales or of Cumberland "through mysterious channels deeply formed underground, into the wells and bore-holes which may be made to receive it," to which theory he tells us "they still adhere."

Personally, I am rather inclined to think that the area from which we receive water is far larger than has hitherto been supposed; for if the hindrance presented by faults to its passage is insignificant, and if it percolates the sandstone with the facility shown by Mr. Roberts's experiments, then we may possibly draw our supply from the uninterrupted and wide area of the Trias which extends over hundreds of square miles to the south-east; but modifying such a hazardous supposition, the area from whose rainfall the wells are supplied must be considerably greater than supposed.

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* Mr. C., however, excludes Wirral in his calculation.

† Mr. Bostock says one-sixth.

The natural condition of most strata, especially sandstone, is to be saturated with water, which flows off at the sea-level—between high and low water mark—and forms springs common in that position. Undoubtedly that must have been the normal condition of this district before the wells were sunk; but since such an enormous quantity of water has been artificially brought to the surface, the natural outflow may have locally ceased, and the reverse action—percolation of salt water from the river—may have set in, and gained access to the wells that are the nearest to it.

I am by no means prepared to prove that the Triassic strata receive water from the underlying and surrounding formations. Yet, what is the probable result of the great dislocations which have thrown the edges of the sandstone, in many places for a thousand feet in depth, against the edges of the Coal-measures for miles along the district? The position of the Trias with regard to the Coal-measures is that of a series of wedges whose sides present very unequally inclined planes, while the strata of both formations are so variously inclined, that beds of shale and sandstone of the Coal-measures and sandstone of the Trias are so intimately connected by faults and overlap, that water must have a very free passage between them.

The supply of water around Liverpool far exceeds all the calculations of probable quantity that have been made, and we must hope that it will continue sufficient not only to supply the wells, but to bank out the sea water and keep it from percolating to any great distance from the river.

SUPERFICIAL ACCUMULATIONS.

During the last year the following papers have appeared descriptive of our local Glacial and Post-glacial deposits:—

"Glacial Phenomena of Western Lancashire and Cheshire," and "Post-glacial Deposits of Western Lancashire and Cheshire." By C. E. DE RANCE, F.G.S. Quarterly Journal, Geological Society, 1871.

"Glaciated Condition of the Surface of the Triassic Rocks around Liverpool." By G. H. MORTON, F.G.S. Report, British Association, Liverpool, 1870. This paper is a *resumé* of the subject up to the time it appeared.

The recent publication of the Geological Survey on the "Geology of the Country between Liverpool and Southport" (already referred to), and the papers by Mr. de Rance, will be read with interest, and no doubt they will tend to elucidate the relation of the Boulder-clay in this neighbourhood to the similar deposits which are so conspicuously developed along the Welsh coast. More inland in Flintshire the higher ground is covered with a Glacial-drift containing local materials, the results of land glaciation, and it differs considerably from the Boulder-clay of the country around Liverpool.

Professor E. Hull, F.G.S., has described in the district around Manchester a Lower and an Upper Boulder-clay, separated by a Middle Sand and Gravel.* At Blackpool, Mr. de Rance has divided the formation into a Lower and an Upper Boulder-clay with Middle Drift Sand or Middle Glacial Sand between them. In the neighbourhood of Llandudno, Mr. H. F. Hall, F.G.S., seems to have established a Lower as well as an Upper Boulder-clay. In his recent paper, read before the British Association (Liverpool, 1870), and published in the "Geological Magazine,"† "On the Glacial and Post-glacial Deposits in the Neighbourhood of Llandudno," he makes a distinction between a Glacial-drift, or Boulder-clay deposited from Glacial-ice, and Boulder-clay deposited from icebergs, limiting the latter term to *débris* resulting from land glaciation.

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* Transactions, Manchester Literary and Philosophical Society, Vol. 2, Series 3; and Geological Survey, "Country around Oldham."

† Vol. 7, p. 509.

Mr. de Rance, in the article published in "Nature" (No. 46), on the "Geology of the Country around Liverpool"—speaking of the Lower and Upper Boulder-clay, states that since his papers were read before the Geological Society, "he has found that the terrace of Glacial-drift skirting the mountains of North Wales, lying between them and the sea, is capable of that division, the cliffs of Boulder-clay east of Llandudnó (round the Little Orme's Head), being distinctly divided by a *Middle-sand*, containing the same species of shells as those occurring in the Lancashire Middle Drift." After this statement by Mr. de Rance, I think that Mr. Hall's bed D, red clay, represents the Upper Boulder-clay, "deposited by melting or stranding icebergs," E the Middle Sand, with the Lower Boulder-clay F beneath, "the result of disintegration by the pressure and passage of land ice."

Although these localities—Manchester, Blackpool, and Llandudno—are distant from our own geological district, it seems certain that the observations that have been made at these extreme points will have considerable value in reducing the drift of the intervening country to a regular order of succession. The correlation of our Boulder-clay and the Lower and Upper Drift Sands below and above it, with the similar deposits to the north of Liverpool and the country south of the Dee, is a subject of great interest at the present time, and it is desirable that your attention should be directed to it.

I am not aware that any shells have been found in the Upper Drift Sand, though about twenty-five species have been collected in the Lower Drift Sand. The same species seem to be common to the Boulder-clay, but no authentic list has yet been made out. In order to work out the Glacial-deposits, it is very desirable that a list of the shells should be obtained, for it would render important assistance. Mr. de Rance divides the Boulder-clay of the country around Liverpool by a thin bed of sand, which occurs at Codling Gap, between Seacombe and Egremont. He considers the bed of sand to represent the Middle Glacial Sand. No importance had been attached to this sand-bed by local geologists before Mr. de Rance described it, but since then Mr. Roberts, F.G.S., has directed attention to a bed of sand in a similar position at Linacre, and to the occurrence of numerous shells in the Boulder-clay at that place. Mr. de Rance does not refer to what I have described as the Lower Drift Sand, which occurs at the base of the Codling Gap section, beneath what he considers to be the Lower Boulder-clay, so that probably it was not exposed when he visited the place. Neither does he refer to the Upper Drift Sand, but seems to include it in his Middle Glacial Sand. Our information regarding the Drift Sands associated with the Boulder-clay of the country around Liverpool is very imperfect, and at present I do not see how we can separate the latter into a Lower and an Upper subdivision. It seems very doubtful whether the Codling Gap sand-bed does represent the Middle Glacial Sand, or either the Lower or Upper Drift Sand, for it is not attended with any evidence of denudation, and may be regarded as a mere local seam of sand, interstratified with the Boulder-clay. Although the communication from Mr. de Rance is a valuable addition to our knowledge, there are many statements to which objection might be made; though I feel confident that it will cause such a thorough examination of our Glacial-deposits as will lead to a satisfactory conclusion regarding them.

You will remember that Professor Ramsay, in his "Ancient Glaciers of North Wales," describes three periods of the Glacial Epoch of that country:—

1st.—A period of glaciation, with the land higher than at present.

2nd.—One of subsidence, when the country was covered with drift—mostly Boulder-clay—deposited by icebergs.

3rd.—Another period of elevation, when glaciers again descended the old glacial valleys, and ploughed out the drift that had accumulated in them during the submergence.

The glacial denudation of the land, and the *débris* brought from a distance by icebergs, produced similar formations, composed of drift or Boulder-clay.

In this district the first of these periods is probably that during which the Triassic sandstone was glaciated, and the Boulder-clay about Liverpool may represent both that period and the subsequent one of subsidence. There can be little doubt that the glaciers which passed over this part of Lancashire and Cheshire had, in some way or other, collected stones and boulders from a distant source; for there is no rock of local origin sufficiently hard to groove the rocks in the continuous and uniform manner in which they have been striated. Still, I do not think that there is any reason to suppose that our local glaciation occurred during the second period of elevation referred to by Prof. Ramsay, but rather that this part of England was not again elevated until the close of the Glacial Period, after the whole of the Boulder-clay in this district was deposited.

In the neighbourhood of Eastham and other places I have detected fragments of Triassic sandstone associated with foreign boulders in the Glacial-drift; these may be undisturbed portions of the Lower Boulder-clay which was formed by the melting of the glacial-ice along the margin of the land, but since denuded or blended with more recent deposits—*débris* derived from floating ice. Mr. de Rance reminds us that "the Upper Boulder-clay is a marine deposit, formed of the detritus brought down by glaciers in the valleys of the Cumberland Lake district to the ice-foot, which melting, carried its spoils over the sea-covered plains."* He also states that "these divisions are more or less seen in the Liverpool district, especially on the Cheshire side of the river, in the neighbourhood of Egremont and Eastham;"* but he has given no details by which we can identify his subdivisions, except at Codling Gap. With regard to the Lancashire side of the Mersey he says:—"In the country between Liverpool and Southport only traces of the Middle Drift occur, and the Lower Boulder-clay is probably alone present." †

In the "Geology of the Country between Liverpool and Southport," Mr. de Rance gives the following arrangements of the drifts:—

Post-Tertiary	Recent.	Blown Sand; Upper "Cyclas"-clay, Upper Scrobicularia-clay.
	Pre-historic.	Upper Peat, Lower "Cyclas"-clay.
Newer-Pliocene.	Post-glacial.	Shirdley Hill Sand, Lower Peat.
	Glacial.	Sand, Middle Drift, Lower Boulder-clay.

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* Notes: Geology, Country around Liverpool, *Nature*, No. 46, p. 393.

† Geology, Liverpool and Southport, p. 5.

In the paper on the "Post-glacial Deposits of Western Lancashire and Cheshire," the same author gives the following correlation of historical periods with the geological formations on the coast of Wirral:—

Recent to Norman Conquest	*Sand dunes.*
Danes and Saxons	B. tentaculata *sand.*
Saxons	*Peat and made earth.*
Saxons and Romans	Tell. balthica *sand.*
Romans and Celts	*Main Peat.*
Celts	,, *lower portion.*
Palæolithic-weapons race	*Lower blue silt.*
No trace of man	*Lowest peat.*

Mr. de Rance has certainly rendered an important contribution on our Post-glacial drift-deposits, and has originated several explanations of local phenomena which have been previously unnoticed; although local observers may easily object to some of the author's descriptions and conclusions. But these are by no means important except to geologists who can afford to work out all the minute details of stratification even by numerous borings, as Mr. Roberts has done along the shore at Leasowe. I will only allude to the somewhat vague statement that the Mersey formerly flowed through Wallasey Pool "even in historical times" ! ! *

In conclusion I thank you for the support I have received during the time I have occupied this chair, and henceforward I hope to devote myself to the welfare of the Society in another office.

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* "Post-glacial Deposits of Western Lancashire and Cheshire, p. 656. But in the Papers on the Glacial Phenomena of the same district he states, that this river," (Wallasey Pool), "now a tributary of the Mersey, can be proved historically to have been once the chief estuary of that river" !!! P. 645.

NOVEMBER 8TH, 1870.

THE PRESIDENT, CHARLES RICKETTS, M.D., F.G.S., in the Chair.

HAMO PERCIVAL was elected an Ordinary Member of the Society.

The following communication was read:—

ANALYSIS OF SOME MINERALS LATELY IMPORTED.

BY A. NORMAN TATE, F.C.S.

DECEMBER 13TH, 1870.

THE PRESIDENT, CHARLES RICKETTS, M.D., F.G.S., in the Chair.

THOMAS MELLARD READE was elected an Ordinary Member of the Society.

The following communications were read:—

REMARKS ON THE LOWER SILURIAN ROCKS IN THE NEIGHBOURHOOD OF LLANFYLLIN, AND ON THE CONTORTIONS OF THE STRATA.

BY CHARLES RICKETTS, M.D., F.G.S.

THE lowest strata in the Llanfyllin district are situated in the interesting locality of Craig-y-glyn, a mile and a-half north of Llanrhaiadr yn Mochnant, and ten miles due west of Oswestry. They consist of a series of dark slates, above which is a thick bed of calcareous volcanic ash, very fossiliferous, in which the occurrence of current bedding indicates its having been a deposit in no very great depth of water; overlying this is a bed of limestone, succeeded by dark sandy slates and shales. The succession of the strata, dipping towards the south, is made very evident in the precipitous sides of the channel which the rapid stream of the Iwrch has cut for itself through the hard and compact bed of volcanic ash. These beds, which have been generally referred to the Upper Llandeilo formation, occur in a very restricted area, being cut off by faults which have thrown down the Caradoc beds on either side. Fossils are very abundant in the ash-bed and limestone, especially *Asaphus tyrannus*, *Orthis turgida*, and an Echinoderm which has not yet been determined, but Dr. Thomas Wright, of Cheltenham, thinks the specimens will prove to be detached plates of *Cystidea* or *Crinoidea*, probably the former. There also were found *Calymene Blumenbachii*, *Trinucleus concentricus*, and *Leptæna* like *sericea*, also *Leptæna sp.*, *Strophomea sp.* (the two last have not been figured by Mr. Davidson, in his monograph on the Silurian Brachiopoda), *Nebulipora lens*, two other Corals, and rings of Encrinites.

In the valley of Afon Rhaiadr and of Nant-y-Llyn, which is an extension of the Rhaidar northward, the occurrence of bands of volcanic ash and felspathic trap have had a very material effect in the excavation of the valley. The stream commences in a small lake, the half of which is encircled by a steep escarpment, rising almost perpendicularly to 250 feet or more, consisting of slates having, about 40 feet above the lake, a thick band of greenstone interbedded, the debris from which has, about a quarter of a mile from the lake, formed a moraine-like heap nearly covered with peat. This peat-bed continues as far as to where the stream passes over a bed of felspathic trap, and forms a succession of cascades into a deep ravine, which has resulted from the more easy disintegration of the slate rock, whilst the summits of its sides are protected by the thick band of trap. Lower down the valley, and about four miles from Llanrhaiadr, this same band of trap rock has, in consequence of its hardness, prevented the excavation of the valley of Afon Disgynfa being carried to so great an extent as in the more easily disintegrated slates of Nant-y-Llyn, thus forming, where the waters of the two streams join, the picturesque waterfall of Pystil Rhaiadr, having a perpendicular fall of 240 feet, the highest in North Wales.

At Cwm Gwnnen, four miles from Llanfyllin, in a northwesterly direction, there occurs, interstratified with the Bala Limestone, a bed of a dark black colour, 15 inches thick, abounding in Phosphates; it is extensively worked, the material being conveyed to this town for conversion into artificial manure.* A section and description of the strata in this locality have been given by Mr. D. C. Davies, of Oswestry, in the "Geological Magazine, 1867," page 251. The rocks have been disturbed and bent in a remarkable manner, being reversed along the ridge of this, the Das Eithen range, but in the valley, and more distinctly in the mine, they are seen curving round towards their proper

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* Mr. A. Norman Tate has favoured me with the following analysis of a sample from the Phosphate-bed; it differs from a former one, in which the relative amount of Phosphates was considerably greater:—

Moisture	2.100
Carbonaceous Matter, resembling Graphite	2.016
Phosphate of Lime	43.400
Phosphates of Iron and Alumina	7.200
Sulphate of Lime	3.404
Silicate of Lime	5.720
Carbonate of Lime	9.760
Silica	26.400
	100.000

position. Along the Llanfyllin turnpike road from thence, the strata are frequently nearly perpendicular, and in the hill called Gallt Glan Tanat are seen dipping at a high angle, forming on its southern flank near the base a synclinal curve. On a line from this to as far as the Green Hall quarry, east of Llanfyllin, very great contortions have occurred, the strata being in several places quite perpendicular, and in the quarry the Bala Limestone forms, from the vertical, an "o gee" curve, and the beds of shale which surmount it are even reversed.

Seeing that these disturbances are so remarkable, the question as to their cause will naturally be forced upon our consideration. Contortions such as these are attributed to the action of lateral pressure; and slaty cleavage is now generally considered to have been caused by similar pressure, and occurs likewise in localities where there has been such disturbance of the strata; it is therefore probable that both the contortion and the transverse cleavage are dependent upon the same series of changes. If upheaval of the land takes place, tension will be induced, resulting in fissures which will extend from the surface downwards, widening as the land becomes more raised; also, and as a consequence of the rocks thus losing their support on one side, masses would be detached along the margins of their fissures, forming as it were landslips, and therefore faults. These wedge-shaped fragments, as the fissures become wider and more extended, will, by dropping downwards, fill them up, and by so much increase the horizontal area of the land. If this enlarged area afterwards subsides, it must of necessity, in order that it may resume the space which it originally occupied, be exposed to compression laterally, by which the rocks will become bent and contorted, and, if consolidation has not commenced, there would also occur, from the same lateral pressure, that re-arrangement of the particles of which the strata consist, upon which transverse or slaty cleavage depends.*

Similar effects would be produced in subsiding districts, and upon their being raised by pressure from below. The depression of the land below its original horizon would cause tension and fissures extending from the interior towards the surface. As in the former case and from the same cause, faults would occur, the detached mass filling up the interval. Upon subsequent upheaval, compression, contortion, and slaty cleavage would occur, to an extent commensurate with the area occupied by the increased amount of rock mass included between the faults, and the extent to which the strata are raised towards, and as far as, the level of the horizon. As a rearrangement of the particles of which the rocks consist could only take place before consolidation of the deposit, and as the cleavage is dependent upon lateral pressure, it will probably have more frequently occurred upon the upheaval of a subsided area, than by the depression of one which, having been raised, it may be to above the sea level, had become consolidated by having been drained of its excess of water.

THE THEORY OF COLONIES.

By Robert A. Eskrigge, F.G.S.

The chief function of a Society like ours is undoubtedly the collection and publication of geological facts with as little theorizing as may be possible; and it is a good omen for the welfare and durability of this Society that most of our communications are of such a nature.

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* When this paper was read it had escaped my notice that the late Professor Jukes had proposed a similar explanation for the cause of *contortions* in strata. ("Student's Manual of Geology, 1862," page 262.) The idea occurred to him independently, but he states that Professor Phillips had previously arrived at similar results from similar reasoning.

Nevertheless, few minds are so constituted as to be able to go on month after month and year after year patiently gathering facts, without some effort to discover those general laws of which the isolated facts are merely particular instances. To dwell constantly on detail tends to cramp the mind, and one experiences a sense of intellectual expansion and relief as one surveys the wider circle of thought necessitated by the examination of any comprehensive theory.

We trust, therefore, we shall be excused if, not having any fresh results of personal research to bring before you, we occupy your time for a few minutes with a statement and consideration of the Theory of Colonies first propounded by M. Barrande, and which recent investigations and discussions have brought into prominence. It is well known to all of you that the distinguished geologist just named has investigated for many years, with untiring patience and energy, the stratigraphical succession and fossil contents of the Silurian Basin of Bohemia—where the whole series from the Lower Cambrian to the top of the Silurian seems to be singularly complete—and that he has demonstrated by suites of fossils, unexampled in numbers and perfectness from one country, a general and indeed very close similarity between the fauna of his successive stages and those of beds in our own country and elsewhere. The general parallelism of the Bohemian beds with our own is most striking; not only the genera but many of the species being exactly similar in both, and, what is more important, *appearing in the same order*, thus sustaining the broad principles of geological classification which are now universally recognised.

The discovery in North and South Wales in recent years of extensive beds of the so-called Primordial Zone has still further *confirmed* the conclusion that the succession of animal life in Britain and in Bohemia has followed a similar law of connection and progress.

Speaking broadly, M. Barrande's observations have fully supported what seems to be the general law of succession for all geological periods—viz., that whilst some genera and species have a wider extension both in time and space than others, there is with these as with individuals, a constant dying out of old forms and replacement by new ones, and that as a rule when once a genus or a species has become extinct it never reappears, and, still more, that when once a group of animals that have lived together disappear they never occur together again.

To this general rule, however, M. Barrande has found at least one very remarkable exception. In his stage D, which corresponds to the upper division of our Lower Silurian, (say to Upper Llandeilo, or Bala-beds), he discovered a fauna composed of 63 species, only two of which were found in the beds immediately below; whilst 57 were identical with species common in the beds of the higher stage E (Upper Silurian, Wenlock, &c.), from which they are separated by some 3,000 feet of strata. The remaining four species out of the 63 appear to be peculiar to the intercalated beds.

Now, except these 57 species (which occur together in beds lithologically quite different from those of stage E), very few forms of animal life run up from D to E; there are a few, but they belong to those classes which we know to be most persistent in their duration, such as Lingulæ and corals.

The phenomenon, then, is a remarkable one; a group tolerably numerous, highly diversified, consisting of eight species of Trilobites, twenty Cephalopods, nine Brachiopods, twelve Acephala, and eight Corals, Graptolites, and Encrinites, suddenly occupy a certain area, to the complete exclusion of its former inhabitants. This community flourishes there for a long period, dies out as suddenly as it appeared, and is succeeded by thick beds of quartzite, similar to those which underlie it, and containing the characteristic fossils of stage D. These quartzite-beds persist through 3,000 feet, and at length, disappearing altogether, give place once more to beds the exact counterparts of the intercalated ones of which we have been speaking.

It is not in one locality only that this succession obtains, but on both sides of the central axis of the country the sequence is identical; this excludes all ground for the suggestion of a concealed fault or faults as the explanation of the phenomenon. Moreover, the beds in question conform in both dip and strike to those above and below them.

To this group of animal remains M. Barrande has given the apt designation of a Colony, and suggests as the only satisfactory explanation of the facts, that in some other, probably not very distant locality, a parent society of Upper Silurian forms flourished during the deposition of the Lower Silurian beds in the Bohemian basin, and that, owing to a change in the direction of oceanic currents or the removal of some barrier, a migration from this society took place into the Bohemian area; that after these conditions, favourable to the interchange of fauna, had subsisted some time, the old conditions which prevented migration recurred; and when these had been in operation an indefinite period, communication was once more restored, and the fauna, of which the Colony had been merely an advanced detachment, took full possession of the area in question.

But how does this explanation harmonise with our generally received notions of the contemporaneity of formations containing identical or closely allied faunæ? We are called upon to believe that in this parent locality an Upper Silurian fauna flourished during all the time occupied by the deposition of the so-called colonial beds, and the 3,000 feet of overlying Lower Silurian quartzites; in other words, that in areas not very distant an Upper Silurian and Lower Silurian formation were absolutely contemporaneous. The only alternative hypothesis would be that we have in the Colony an instance of a sudden creation of a new fauna, and after its complete extinction a re-creation of identical forms after the lapse of long ages. This, I imagine, we shall scarcely be prepared to accept.

But before giving adhesion to M. Barrande's hypothesis, it will be well for us to see if this fact is an isolated one, or whether others can be adduced tending to the same conclusion.

M. Barrande himself has felt the justice of this requirement, and so long as the phenomenon appeared to stand alone his explanation of it was advanced with diffidence, and met with little favour from contemporary geologists, who regarded it as destructive of all established theories.

The discovery of Lower Silurian forms intermingled with a true Primordial fauna was another link in the required chain of proof.

Further investigations have also revealed the very remarkable fact that the stages E and F, or lower beds of Upper Silurian, contain a closer approximation to the Devonian fauna than the overlying beds G and H, which are nearer to it in point of time. So clear has the evidence on this point become by close investigation that, as we learn from Professor Huxley's late anniversary address to the Geological Society in London, the Austrian geologists have at length, and sorely against their prepossessions, been compelled to admit the validity of M. Barrande's facts and reasonings. Other countries and formations also furnish some corroborative evidence. In a very interesting paper read before the Geological Society in 1853, by Mr. Godwin Austen, on the Palæozoic rocks of the Boulonnais, we find the following passage:—"At intervals which are widely apart in time, such as are represented by the limestones of the lower division (Ferques Limestone down to that of La Cedule), and when somewhat like conditions are repeated, we meet with a recurrence of identical forms, which prove the continuity of the same general fauna. In this, as in all such cases, the occupancy of an area under any new conditions must necessarily have been by a process of immigration."

He adds:—"This consideration is of some importance with reference to all attempts at systematic classification. Like mineral groups with identical faunæ are not necessarily synchronous; whereas many groups with nothing whatever in common, whether in respect of mineral composition or included fossil forms, must of necessity be of the same age."

At least two examples of the same class of facts may be adduced from the geology of our own country. In the Northwest Highlands of Scotland occurs a quartzite rock, with bands of highly crystalline limestone, containing a group of fossils, evidently Lower Silurian in their general character, but differing from any other group in this country.

A very careful examination of them, however, by competent palæontologists has revealed their close similarity, if not identity, with the fossils of the Lower Silurian rocks of North America ranging from the Calciferous sand-rock up to the Trenton Limestone. The beds are similar in lithological character, and we can thus scarcely resist the evidence that we have here an outlying Colony of the great western community—not necessarily contemporaneous, indeed most probably not so, for all analogy leads to the conclusion that animal migration takes place slowly.

Nor does this fact stand alone. Mr. Bigsby, in his very interesting "Thesaurus Siluricus," shows good ground for believing that the western area now occupied by America was peopled by Silurian forms before our own, and that the European area derived many of its genera and species thence by immigration. This is especially the case with regard to what is known (though we think the name unfortunate) as the Primordial Zone.

In a paper contributed to the Geological Society by Mr. Brodie, printed vol. 6 of Qu: Jo:, we find an account of a similar repetition of fossil forms in the Oolite. In the lower part of the Inferior Oolite, near Leckhampton, there occurs a band described as a shelly freestone full of fossils, though many of them are in a fragmentary state, but still sufficiently perfect for specific determination. In lithological character this band precisely resembles the Great Oolite at Minchinhampton and elsewhere; the animal remains are to a great extent identical. In a series from the Leckhampton beds sent to Mr. Lycett for examination, he identified 52 out of 152 species as hitherto supposed to be characteristic of the higher formation.

Geologists familiar with the fossils of the Great and Inferior Oolite, previous to the discovery of this bed at Leckhampton, would scarcely believe that the specimens from the latter place really belonged to the Inferior Oolite, so nearly did they resemble those of well-known Great Oolite forms. It should be stated that many of the shells were worn and had the valves detached; moreover, the fossils at Leckhampton were generally smaller and less numerous as individuals than the same species at Minchinhampton. If this was a Colony derived from a distance, and which soon died out because the conditions were only partially favourable, we should expect the individuals to be stinted in growth. Even if it were proved that none of these mollusca really lived where their remains are found, but that their shells were drifted there, this does not at all alter the fact of the co-existence in time of the Inferior and Great Oolite, which is the palæontological point sought to be established.

These facts, when fairly considered, are sufficient, we think, to cause geologists to admit that if the term "synchronous" be retained at all, as applied to strata in different parts of the country which contain closely allied or identical faunas, it must be used with a certain latitude of interpretation—not as signifying absolute contemporaneity, but merely that the beds were deposited in the period of time during which similar geological conditions obtained, without expressing an opinion whether that period were long or short.

In order to secure greater clearness of conception on this point, and a more complete harmony between facts so far as known and the terms we use to express them, Professor Huxley has proposed the term "homotaxial" for deposits which contain similar assemblages of fossil forms and appear to have resulted from similar conditions. The term "synchronous" would then apply only to deposits which were proved by independent evidence to be of the same age, and would not imply that their fossil contents were the same. This suggestion appears to us a highly valuable one.

To return, however, to the facts adduced—are they not exactly such as, with our present knowledge of the distribution of molluscan life in sea-bottoms, we should expect? If we take areas widely apart, or some so near as the East and West Coasts of England, or say our own shores and those of the Mediterranean—are not the assemblages of living forms widely different? Yet we know them all to be strictly synchronous; and just as we fully recognise certain terrestrial provinces and admit that emigration and immigration have modified the forms of the mammalia now inhabiting these, why should we not admit that similar migrations of mollusca take place now, when physical conditions are favourable to such movements, and may, and no doubt did, take place in other geological epochs, the traces of which in a few cases modern researches have brought to light.

Instead, then, of ignoring such facts, or endeavouring to explain them by the statement "that similarity of sediment will produce similarity of animal life," a principle which careful examination shows to have only a very limited application—I think we ought to accept them as another proof that the same general laws of distribution prevailed in long past geological epochs as we find to prevail now.

The unwillingness of geologists to accept M. Barrande's theory seems to arise not from any hostility against the particular instance on which it was originally founded, but from a doubt how the principle of it was to be kept within bounds if once admitted at all. Granted that the Upper and Lower Silurian formations were proceeding contemporaneously in two different areas, why should we not have the Lower Silurian contemporaneous with the Devonian or even with the Carboniferous? and if so, might we not have the former sending out a Colony into the latter, so as to overlie it? But if this were so, all our established theories of succession are at once overthrown, and the order of geological deposits once more hopelessly entangled.

There is, no doubt, some force in this objection, but we must be careful not to allow fear of possible consequences—in other words, love of our own pet theories to prevent our acceptance of well-established facts. Moreover, so far as our knowledge extends, there is as yet no instance of any Silurian Colony existing down to or overlapping the Carboniferous period, nor of Carboniferous extending into secondary or Tertiary deposits.

It will not have escaped your notice that in all the cases of supposed colonization which have been adduced, the parent society finds its place within the same general system as the bed which includes the Colony, and that the underlying, intermediate, and overlying beds contain fossils which, whilst they differ generically and specifically, yet retain such a general resemblance as to be recognisable as belonging to the same life epoch.

In the first named and typical case, the whole period embraced is that represented by the upper beds of the Lower Silurian, and the lower beds of the Upper Silurian. In the case of the Oolites, also, the beds presenting these palæontological resemblances all belong to the same formation, so that no disastrous results to our system of general classification have as yet followed the admission of the principle.

But in these days we are startled by the assertion that we are living in the "Cretaceous Era."

The remarkable results of the dredging expeditions of the "Lightning" and the "Porcupine," conducted by Messrs. Carpenter, Wyville Thomson, and Gwyn Jeffreys, are invoked to prove that, as Professor Huxley phrases it, "the modern chalk found at the bottom of the Atlantic is not only the lineal descendant of the ancient chalk, but is in possession of the ancestral estate." If so, supposing the area of the British Isles were now depressed beneath the sea level, why might we not have another Cretaceous formation overlying the Tertiary and more recent deposits, and yet exactly similar to the ancient chalk which we class as

Mezozoic? Such an event would indeed upset the basis of all our geological calculations.

But when we examine more narrowly the results of this exploration, we find that for the most part the identity of the animal remains in the modern globigerina mud with those of the chalk is confined to forms of very low organization—Foraminifera, Sponges, Actinozoa, &c.—in fact, just those forms of life which we should expect to be most persistent. It seems an established law of animal life that the lower the organization the wider the range both in time and space and the greater the multiplication of individuals. In addition to the forms enumerated, we only know of Terebratula Caput Serpentis and a Beryx recently discovered which are said to be identical with the fossils of the chalk. What has become of the various genera of the family of Cephalopods, of the Ammonites, which then flourished so abundantly? of the Belemnites, Scaphites, and Turrilites? and of the peculiar fish which characterize our old Cretaceous deposits?

We confess we fail to discover the essentials of a Cretaceous fauna in the mud of the Atlantic; and even if a few generic or even specific forms are found to exist still which lived in the days of the old chalk, this is only in harmony with well-known facts of the exceptional persistence through enormous periods of some few individual forms, and is not sufficient to warrant the sweeping conclusion that we are living in the Cretaceous era. It should be mentioned that Mr. Gwyn Jeffreys altogether dissents from the conclusion of his colleagues.

We freely admit, nay more, we most strongly maintain, as we hinted at the outset, that our whole system of geological theory is to be regarded as provisional only; that it may and very probably will require modification, as fresh facts are being continually brought to light. As such we are prepared to hold it loosely, and to defend it only as the most convenient and natural mode of arranging facts, and explaining them according to our present knowledge.

But after this admission we must also say that the sum of geological knowledge seems to us very clearly to teach that, owing to the action of some inscrutable law, the succession of life in different parts of the globe has followed the same general order, so that the faunas of widely-separated areas may be correlated as presenting a broad and general similarity; that this does not imply that similar deposits were absolutely synchronous, but that they belonged to the same life epoch; and lastly, that the instances of recurring faunas or Colonies, so far as now known, are not sufficient to subvert the above principle, but show merely that different modifications of the same fauna have existed contemporaneously, just as varieties of animals having a common ancestry exist in the earth now.

JANUARY 10TH, 1871.

THE PRESIDENT, CHARLES RICKETTS, M.D., F.G.S., in the Chair.

Rev. CHARLES KINGSLEY, M.A., F.L.S., and HENRY BEAZLEY, were elected Ordinary Members of the Society.

The following communication was read:—

OBSERVATIONS ON METALLIFEROUS DEPOSITS.

BY ALFRED MORGAN.

I AGAIN bring before the Society the subject of Metalliferous Deposits. My former paper* referred principally to the origin of the fissures and other cavities that now contain metallic ores, and contained a *resumé* of the various hypotheses that have been advanced to explain the phenomena connected with them. I have not been able to carry out, as I had intended, a systematic examination of the mining districts of Flintshire. The present paper will chiefly consist of critical observations on the various theories of mineral deposition, more especially those that are termed Segregational theories, and theories of Aqueous precipitation. In no department of geological science have theories more divergent been put forth; and I am warned at the outset of the dangers that attend the use of that most despotic of faculties—the imagination—even when it views scientific subjects in conjunction with great intellectual ability. The paper referred to above described the undoubtedly mechanical formation of the fissures and other cavities that now contain ores. In most instances they are analogous to the ordinary faults of geological strata.

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* Proceedings, Liverpool Geological Society, 1869–70, p. 37.

The different theories that have been promulgated to explain the origin and formation of Metalliferous Deposits may be grouped under three heads:—

A. Theories of Sublimation.
B. „ Segregation.
C. „ Aqueous Precipitation.

With regard to the first group: the constant characteristics of mineral veins are altogether opposed to those theories which take sublimation alone as their basis. They necessarily involve the supposition that all such fissures, extending to a vast depth, and becoming the medium of escape for large volumes of subterranean gases, were filled first in their lower portions; while it is the observed rule that veins become poor, and finally destitute of ores, as we descend into their lowest sections. As an instance of the deposition of crystalline matter on the walls of a fissure, Von Buch observed at Lancerote, in 1815, an open rent traversing the walls of a volcanic crater formed 84 years previously. From this crater vapours were still issuing at a temperature of 84° (Fahrenheit), and had deposited hydrate of Silica on the sides of the cavity, the incrustations extending nearly to the centre; but he does not mention having observed any trace of metals.

Not only is there an entire, or almost entire, absence of anything like evidence of such conditions having prevailed, but it is usually found that the ores of metals occur most abundantly in the upper portions of the veins, or even in pockets at their surfaces. Heat, that most powerful and subtle agent of change, even when not allied with such conditions, could not have passed through the veins without leaving some traces of its action.

The Second Group—Theories of Segregation.—Under this head I propose to include the action of Hot Springs. Although we are led to infer that an intimate connexion has existed between metalliferous veins and thermal springs, we must not on that account suppose that the contents of both would be identical in their nature. M. Elie de Beaumont has pointed out that, notwithstanding their intimate relationship, this is not to be looked for; the fact being that those substances which are least soluble are not discharged by hot springs, because in the upward flow of the waters each change of the temperature as they rise to the surface causes a precipitation of the least soluble particles on the walls of the fissure; while the alkalies and other readily soluble substances are retained in the waters and discharged. Many of the substances with which hot springs are impregnated occur as vein stones—*e.g.*, Silex, Carbonate of Lime, Sulphur, Fluor Spar, Sulphate of Barytes, Magnesia, Oxide of Iron, &c., &c. Prof. Daubree,* one of that distinguished company of *savans* who combine the experience of the engineer with the skill of the chemist and the zeal of the geologist, has shown how the natural action of warm springs flowing from the Vosges Mountains has generated Zeolitic and other minerals, differing in their nature according to the materials they traverse. He cites the waters of Plombières, which, issuing from a granitic region, yield Fluor Spar and Quartz at a temperature of 73° Cent., = 163° Fahr., and hold Silicates and Fluorides in solution. These waters, acting upon the masonry in the old Roman bath channels at Plombières, have penetrated the mass, and generated in the cavities Apophyllite, Chabazite, and other Zeolitic minerals—Opal, Arragonite, Calc-Spar, Fluor Spar, Hydro-Carbonate of Magnesia, &c. These minerals, we are told, have not all been brought by the waters; many have been derived from the bricks and cement over which they have passed. These remarkable results suggested to M. Daubrée an analogy to the eruptive igneous rocks, which often contain Zeolitic minerals—*e.g.*, the Basalts and Amygdalloids — and led him to infer a similarity of origin. With higher temperature it is probable that even anhydrous Silicates might be displaced and replaced, and thus explain the filling of many veins, and many metamorphic phenomena which it would appear are due rather to heated solutions than to heat alone. If in the remoter geological periods we may assume the existence of a heavier atmosphere, and consequently, at sea level, a higher boiling point of water, together with an increased temperature of terrestrial bodies, it follows that the solvent power of water would be very much increased. Perhaps we could not find a better illustration of the extent of this solvent power of water than is afforded by the Icelandic Geysers, which are ever producing great changes.* Bunsen, from careful personal observation, arrived at the conclusion that none of the rocks of Iceland were capable of resisting the solvent action of hot water. This agent of perpetual change breaks up traps, lavas, &c., either by liquid flowing or steam condensing. It removes the separated parts, dissolving some, depositing others, and forming continually new earthy combinations diversified by sulphates and sulphurets. We may suppose that in the past epochs of metalliferous deposition the atmosphere may have sustained, by reason of increased temperature, a larger proportion of aqueous vapour than at present (at 21° this amount would be doubled), which would retard radiation of heat, and so greatly add to the solvent power of water. If we may imagine the lower eruptive rocks to be the original source of the metallic elements, the water would at great depths eliminate these elements and deposit them at a higher level, regulated by the temperature of the fissure and by the variable conductibility and chemical affinity of the rocks. As the heat decreased, in consequence of the diminution of Plutonic activity, the metals would be deposited lower down in the fissure. This view is entertained by Cotta. He also supposes the eruptive force to have opened fissures from time to time during a long period, and that through these fissures water, probably the water of the ocean, penetrating to a great depth found in the heated, deeply-seated masses of hypogene rocks those earths and metals which are soluble under a combined high pressure and temperature and the coöperation of alkalies, which the waters would supply. Of the earths, he found Silicic Acid when dissolved crystallised again at a very high temperature. For this reason it is, he supposes, that it fills principally the oldest fissures, or forms the older portion in newer ones. The other minerals would follow according to their capacity for reduction or solidification. By this theory he seeks to explain the absence or rarity of ore veins in the newer eruptive and sedimentary rocks. The continued cooling of the earth has, he says, necessitated a depression of the zone of deposition, and when now carried on it is only at great depths. To Prof. Cotta's theory it has been objected that, though the metals are found abundantly near the junction of stratified and eruptive rocks, they very rarely occur *in* the eruptive rocks themselves; and when they do it is usually found that, although a vein may be very productive near the surface, the ore fails as we descend into the crystalline rocks. "If the metals," it is urged, "come from below, how is it that the granite is so poor for ores?" To this Prof. Cotta replies:—"It is only where a *rapid cooling* of the eruptive mass has occurred that we should expect to find metallic ores; where the mass has cooled slowly the specific gravity of the metals has carried them away to vast depths. The rapid cooling might be expected in the case of vein masses, or porphyries, or 'elvans,' and in small 'stock masses,' or in contact surfaces of large masses; and it is just in these positions that we find ore deposits most abundantly."

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* Sur la production artificielle de quelques espèces minerales. (Ann. des Mines, 1850.)

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* *F. A. Phillips* on Mineral Veins in California, p. 320.

The theory of Prof. Cotta is defective in the assumption of the water in the fissures having been the water of the ocean, not the water of deep springs. Chemical analysis shows us that the waters of all springs are impregnated with mineral substances. In mineral springs not only is the proportion of such ingredients very largely increased, but they are found to correspond remarkably in their nature with those evolved in a gaseous form by volcanoes. This is particularly observable in thermal springs.* Such springs are probably caused by columns of steam, mixed with other gases, being condensed before reaching the surface by coming in contact with strata filled with cold water. Volcanoes, as we know, in eruption give off steam and other heated gases in enormous volume, often for very long periods; and, for ages after the volcano has spent its force, hot springs continue to flow at various points in the same area. Coming from great depths, where under increased pressure they have exerted a powerful disintegrating influence, it would seem that thermal springs are the great agents of mineral deposition. According to Henry, water under a hydrostatic pressure of 94 feet will absorb three times as much carbonic acid gas as it can under ordinary atmospheric conditions. There are other gases, as well as carbonic acid, which water absorbs, and more rapidly in proportion to the amount of pressure. The water of thermal springs acts not only as a vehicle of heat, but also, by its affinity for various Silicates when some of the materials of the invaded rocks are decomposed, forms Quartz, Felspar, Mica, and other minerals. As for Quartz, it can be produced under the influence of heat by water holding alkaline Silicate in solution—as in the case of the Plombières springs—without any chemical reaction. According to Daubrée, Silicate may be produced in a moist way at a very much less temperature than by a dry heat.

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* Lyell's Principles, 10th Edition, Vol. 1, p. 394.

We learn from Prof. Bischoff* that the stream of a hot spring at Aix-la-Chapelle, which I had the pleasure of visiting last summer, the temperature of which is only 133° to 167° Fahrenheit, has converted the surface of some blocks of black marble into a doughy mass. May not the decomposition of the granites and elvans in the mines of Cornwall, to which attention has been called in the treatises of Sir H. de la Beche, and R. W. Fox, be due to a similar cause? Sir H. de la Beche remarks† that at Penstruthal Copper Mine the lode had been tried unsuccessfully at various times in parts where the granite was hard; but trial being made where that rock was soft, it became one of the most profitable mines in Cornwall. The same fact is observed in St. Austell and other districts.

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* Edinburgh New Philosophical Journal, No. 51, p. 43.

† *Geological Observer*, p. 781. Ibid, p. 786.

Another theory is that of Infiltration. It supposes that water percolating the surrounding rocks has eliminated various mineral elements, and after conveying them to the vein has deposited the ores, &c. in a form analogous to the stalactitic encrustation of caverns. We are told that, in every sedimentary formation Lime, Silica, and Iron, *e.g.*, are found more or less abundantly, and that these materials were probably held in solution by the waters of the ocean when the rocks were deposited.

But it should be remembered that, though copper, tin, and lead, and other minerals which are most frequently obtained in lodes, are found occasionally in these rocks, it is only in minute quantities scattered over wide areas; and it is difficult to understand how one mineral can be withdrawn, as this theory supposes, and its place occupied by another wholly different. It also involves a constant circulatory movement continually in progress in the matrix of some of our most homogeneous and extensive formations. The Carboniferous Limestones, for instance, yield lead, calamine, iron, &c. Yet Mr. Moore states that chemical analysis will show that the elements necessary to the production of these minerals are almost entirely absent from them over wide areas.* The geologist has frequently to call to his assistance the aid of the chemist. There is no science more comprehensive in its grasp than that for the study of which our Society exists.

One of the most important treatises that have been written on the subject of "Mineral Deposits" is that by William Wallace.† This work, though referring primarily to the district of Alston Moor, contains much valuable information, the result of careful personal observation. Mr. Wallace describes the local peculiarities of Alston Moor, such as the directions assumed by the lodes and the cross veins; and accompanying his book is a valuable map illustrating the northerly and southerly direction of the former, and the easterly and westerly direction of the latter. Mr. Wallace's theory of the infilling of veins is that of Infiltration, allied to atmospheric causes and recent hydrous agencies. He observes:—"In Alston Moor* the veins are most productive in situations furthest removed from Plutonic action; the richest deposits are found in the upper portions of the Mountain Limestone, where no igneous rocks are found, either in the form of dykes, or sheets intermingled horizontally with the stratified rocks." He enters very fully into the laws of hydrous action; and in common with Job, Lucretius, Thales, and many ancient philosophers, he entertains a very high conception of the part performed by streams in the mundane economy. The only conditions, he states, that are favourable to the deposition of minerals are the free percolation of water from the earth's surface, and its unimpeded circulation in the vein-fissures. And these conditions only occur where the strata are situated at moderate depths and at a considerable distance from the water-shed of the mountains.†

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* Moore, British Association Report, 1869.

† "*The Laws* which Regulate the Deposition of Lead Ore in Veins," *&c.—W. Wallace.* London: Stanford, 1861.

In estimating the probable effects of such aqueous agencies, he states that we must take into account the increased proportion of carbonic acid gas that is held by the atmosphere in elevated districts. This is absorbed by rain water, in addition to Nitric Acid‡ and Ammonia, together with other ingredients which it derives in its flow from the decay of plant and animal organisms. He quotes an observation of Fournet's to the effect that the metalliferous gneiss near Clermont, in Auvergne, is quite saturated with free carbonic acid gas, which gas rises plentifully from the soil, and has exerted a powerful disintegrating effect.* Such discharges are by no means rare, but it is probable that they are due to deeply-seated Plutonic causes, rather than to superficial ones. We have all observed the effect of atmospheric carbonic acid upon Limestones, and Mr. Wallace frequently alludes to its action in the Alston Moor lodes.

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* Wallace, p. 99. † Wallace, Book 2, Chap. III.

‡ Humboldt's Cosmos (Bohn) Vol. 1 p 317.

Mr. Wallace† states that in this district "the lead-ore has been lodged in the veins chiefly since the glacial epoch;" also that the process is still in progress. He further states‡:—"In the Tyne-bottom mines there is reason to suppose that the lead-ore has been deposited in the flats at a comparatively recent period, and one *long posterior* to the glacial epoch," &c. Mr. Moore, in his article in the British Association Report, quotes this opinion; but Mr. Wallace, in a note to me, says he does not entertain it. I conclude he either inadvertently expressed it, or has subsequently renounced it.

My friend Mr. Eskrigge kindly drew my attention to a theory put forward by a Mr. Thomas Belt, in a pamphlet published in 1866.‖ Mr. Belt refers to the soft, decomposed character of the enclosing rocks, as frequently observed in Australia, as conclusive evidence that the veins have not been filled by means of infiltration. His theory may be summarised as follows:—§ "A mass of sedimentary strata comes under the influence of internal heat, and is molten. The Sillica, which he supposes to be in excess, sinks to the bottom, carrying with it the greater portion of the metals. This process he supposes to have taken place beneath a comparatively thin crust underneath the ocean. Fissures would be produced during the process of cooling, and as these extend to the lower portions, the Silica would be injected into them charged with the various metals. He speaks of the analogy between trap dykes and mineral veins, and is of opinion that granite is of igneous origin. He states that gold is frequently found alloyed, and that heat is the only known means of producing alloys. He considers that the phenomena of lead and copper veins, &c. are due to the subsequent re-arrangement by aqueous, chemical, and electrical agencies of the original vein-stuff."

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* Lyell's Elements, 6th Edition, p. 732. † Page 231. ‡ Page 247.

‖ "Mineral Veins, &c." Thomas Belt. London: J. Weale.

§ Abridged from Mr. Eskrigge's Synopsis.

We now come to the third hypothesis — Aqueous Precipitation. I will take Mr. Moore's article as the best enunciation of the theory.*

In Mountain Limestone districts we find abundant evidence of marine denudation. "Swallet Holes" also occur; that is, openings through which water now passes down into lower levels of strata; and after passing along lines of subterranean fissures, the stream reappears at long distances away from where it entered the rocks; having, like the Peloponnesian Alphæus, flowed, perhaps for miles, underground.† The great majority of open fissures have probably been subjected to the action of *marine* currents. In the South Wales and Mendip districts the evidence seems, beyond doubt, to establish the supposition that the Limestones formed the sea bottom during Triassic, Liassic, and Oolitic times. These districts may be taken as typical. In such localities the most valuable deposits are found in lodes, in bunches or pockets, and sometimes in Flats. The Vron Fawnog Mine, near Mold, in Flintshire, is considered to be one of the most remarkable of the latter kind of deposits. Associated with the ores, and in a much larger proportion, occur a variety of substances such as clays, which are termed *dowks*. These dowks are sometimes conglomeratic, and contain angular and rounded pebbles. The former are probably detached portions of the vein fissure, while the latter are derived from a foreign source. Mr. Moore also found in the dowks fossil wood. In Charterhouse Mine he says:—"I have found a piece of wood converted into jet, the cellular portions containing galena. Similar pieces were found in other mines. Mr. Moore has given the dowks his very careful attention, and he points out that the larger proportion of organic remains that he has discovered belong to marine species, and testify to the veins having received their contents while within the influence of the ocean, and before the containing strata assumed their present horizon. It will be seen that he is diametrically opposed to Mr. Wallace's theory.

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* "On Mineral Veins in the Mountain Limestone, &c." W. Moore, F.G.S. British Association Report, 1869.

† The River Manifold, in Derbyshire, affords a good example.

Mr. Moore enumerates four necessary conditions:—

1.—The presence of the minerals in the waters of the ocean.

2.—The existence of open fissures communicating therewith.

3.—The existence of the necessary electrical and other conditions in the fissures.

4.—Time.

With regard to the first condition:—It has been established beyond doubt that many of our most important metals exist in solution in the water of the ocean. Malagute, Field, Piesse, and others have detected silver, copper, &c. Those who entertain the hypothesis of infiltration suppose the metals to have been deposited contemporaneously with the rocks as precipitates; but the most important query is—From whence do the waters of the ocean derive them?

The second condition—Open fissures communicating with the superincumbent ocean:—It would seem probable that in nearly every instance the veins communicated with the surface, and when a later rock has closed up the vein it will be found that an interval of time has probably elapsed, quite sufficient to allow of the deposition of the ores before the rock closed up the fissure. Mr. Moore refers to the Mendip rocks. The veins contain Triassic fossils, while the capping is sometimes Inferior Oolite.

In those cases where there has been a rapid infilling with a homogeneous material, the metal is generally poor, for this reason — that one of the necessary conditions—*time* — has been excluded; and, he states, the longer a fissure remained open to the marine waters, the richer it would be in ores.

Fossils found in the mineral deposits are appealed to, to give evidence of the age of the vein enclosing them. But though in the case of the strata themselves, the fossils they contain afford the most conclusive evidence of their relative age and coördination; with the veins it is not so. In many places we find pseudomorphites of several metallic ores in the form of fossils; as at Wiesloch, in Baden, where we find the Limestones of the Muschelkalk, which is one mass of shells, converted into Smithsonite or Carbonate of Zinc.* Again, at Münsterappel, in Rhenish Bavaria, Cinnabar is found coating fish impressions of Amblypterus, and in small crystals in the interior of Calamites. In these and the numerous other similar instances sometimes brought forward, the interchange between the Calcic and Zincic Carbonates in the Müschelkalk, and the infiltration of the mercuric solution, may have taken place at any time since the deposition of the rocks in which they are found.

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* Proceedings, Royal Irish Academy, Vol. X, Part IV, p. 398.

In a valuable paper on the Geology of Bolivia and Southern Peru,* David Forbes mentions the occurrence of mammalian bones in the Santa Rosa Copper Mine. Prof. Huxley, to whom they were submitted, was of opinion that the animal belonged to the camel tribe, and was closely allied to the existing llama of the Andes. He named the species *Macrauchenia Boliviensis.* "The bones are, in some instances, almost converted into copper; or, at least, the pores are filled with that metal."† Fossil wood was also found. Now, had these bones occurred in the deposit itself, it would have settled the question; but it was not so, and Mr. Forbes suggests that the animal had fallen into a fissure and had subsequently been covered up by the *débris* of the adjacent rocks. Into this fissure Cupric solutions would, naturally, be always flowing, caused by the action of water on the ores of the adjoining beds. Interesting as many such occurrences are, they are seldom of much value in helping us to determine either the relative age or other questions connected with metalliferous deposits.

Prof. Sullivan and Mr. J. P. O'Reilly‡ speak of a remarkable fissure in the Limestone, in the valley of the Udias. This fissure was filled up with hydro-carbonate of zinc, in which were *embedded* numerous mammalian bones and teeth, probably those of *Elephas Primigenius.* This instance is cited by the authors as the first in which the geological age of any ore, and the conditions of its deposition are determined; but there appears to be no evidence that the fissure had not been re-opened, and that perhaps successively.

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* Proceedings, Geological Society, November, 1860.

† Proceedings, Royal Irish Academy, Vol. X, Part IV, p. 398.

‡ "Notes on the Geology of Santander, &c." London, 1868; p. 66.

Prof. Sullivan, in a paper in the Proceedings of the Royal Irish Academy,* refers to some very interesting observations made by him in 1867 at Stolberg, in Rhenish Prussia. The group of mines are known as the Albertsgrube. The lodes contain clay and sand. Galena occurs in large lumps in the clay. He also found, abundantly, peat or brown coal, small stems of herbaceous plants, wood, and mammalian bones, containing "*a very small quantity of lead.*" † Here, too, there seems no reason why the occurrence of these materials may not be accounted for by supposing the veins to have been re-opened during successive periods, in which the superincumbent and adjoining strata were exposed to forces of denudation. There seems very little doubt that these substances were more recently washed into the fissures, though the author strives to maintain Mr. Moore's theory, and claims for them a contemporiety with the ores.

In conclusion, it seems most probable that veins were originally channels by which hot springs holding the elements of the metals in solution made their way to the surface. The deposition of the ores on the walls of the cavity would take place in obedience to the laws of chemical affinity, of the increased temperature and pressure then existing, and of the earth's electricity and magnetism. Such springs may have had a submarine outflow, but theories like that of Prof. Cotta, which suppose the waters in the fissure to have been derived from a superincumbent ocean, are inadequate. Organic remains are probably due to denudation, &c., and do not afford reliable evidence as to the age and conditions of depositions of vein minerals.

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* Vol. X, Part IV, p. 399. † Ibid, p. 400.

FEBRUARY 14TH, 1871.

THE PRESIDENT, CHARLES RICKETTS, M.D., F.G.S. in the Chair.

GEORGE YATES and WILLIAM PEARSE were elected ordinary members of the Society.

Mr. MARRATT made some remarks respecting the late Dr. TRAIL, who formerly resided in Liverpool, and the collection of minerals and fossils formed by him—now in the Royal Institution—was exhibited in the Museum.

The following communication was read :—

ALTERNATIONS OF SEA AND LAND ASTRONOMICALLY CONSIDERED.

BY ROBERT BOSTOCK.

A SLIGHT acquaintance with Geology serves to show that parts of the Earth's surface must have been sea and land, hundreds if not thousands of times in succession. Perhaps it may not be within the bounds of human knowledge ever to thoroughly understand how these alternations have occurred, but I have long thought whether it may not have been owing to changes the Earth has undergone, as it slowly attained to its present spheroidal form, from a former and far more oblate one. It is scarcely requisite to offer evidence of such change, it being impossible to conceive of the Earth as having always been such as it now is—it follows from the law of continuity, or cause and effect, that it could only have become a sphere in a gradual and imperceptible manner from some other form. The Earth, the Solar System, the Universe—in fact all we can see or even imagine—all is but a result of endless mutations. From a glance at the other members of the Solar System, we may judge of the phases the Earth has already passed through, and what it must ultimately become.

The planet Mercury is perfectly spherical. Venus is so near it, that no flattening is perceptible. The Earth is nearly a sphere, its departure from it being but 1 in 300—its equatorial diameter being about 26 miles greater than its polar. In Mars, the flattening amounts to $\frac{1}{38}$ of its bulk. Jupiter, $\frac{1}{14}$. The equator of this planet is 3500 miles higher than its poles, being kept up to this altitude by its rapid rotation. Saturn is $\frac{1}{11}$. From this we learn the possibility of planets having other forms than that of our Earth, and also that no forms are permanent. Assuming that planets are subject to change of form, let us go back in imagination to the period when the Earth had somewhat the form of Saturn, viz., that of a flat orange, less dense and much larger, its crust thickening, and the whole shrinking in bulk, what would be the effect of such compression on the fluid and gaseous interior—gas we know when subjected to pressure, takes a spherical form—what part of the Earth's surface would be the first to give way? Without doubt it would be the polar regions, these being comparatively flat and consequently weak, would, of necessity bulge outwards, giving rise at the same time to a downward movement at the equator. Thus I imagine the Earth has gradually become what we see it, from the time it was first environed by its stony envelope, from the poles to about the 40th degree of latitude. The land has been rising at intervals, and will continue to do so until it is a few miles higher at each pole. Then, when every part of the Earth's surface is at an equal distance from the centre, when it is perfectly spherical, subsidence and elevation must of necessity cease, it may, however, still continue to shrink in mass.

Then as to water. How water first originated we will not now enquire, but we are assured of its presence at a very early date. There is no rock at present known to us in which water has not played its part. The probability is that its increase was gradual; but whether this increase is still going on, or whether there was formerly more than there is now, there is no evidence to show; but we may venture to speculate as to its effects.

Imagine the Earth consisting of land and water, as at present, but much larger. As refrigeration goes on, the rocky mass shrinks; the effect of this would be to cause the water to appear for ever rising and gaining on the land. To an observer placed upon the Earth, on what now forms Great Britain, at an early date, say the Carboniferous era, the following phenomena would present themselves:—An extensive district a little above the sea, covered by a mass of vegetation; this decays, and is renewed, some of it annually, until a considerable thickness is formed, say forty feet, the sea constantly rising, at length invades the moss or bog, gradually covering it over with silt, now known to us as shale or fire-clay. As the water deepens sand is brought down, this and the silt giving rise to a loamy sandstone—Coal Measure sandstone. Meanwhile, compression has been going on in the interior of the Earth, until at length the tension is such as to fracture the crust, and thrust it outwards or upwards. This, to the observer, would appear as an earthquake, the effect of which would be to elevate the part he had formerly seen submerged. When conditions were favourable, vegetation would recommence, go through the same round, be again overwhelmed by the sea, to reappear again, to go through hundreds of such series in succession. Thus it appears to me, however, that the whole of the alternations of sea and land have been brought about throughout all time. On this view we can understand why Coal-seams could only be formed at a certain period, and why they never can occur again.

To summarise. The history of our Earth would appear to have been somewhat as follows, according to the Nebular theory, which I hold to be the true one. The Earth was detached from the Sun's mass as a vast ring of vaporous matter, whose diameter must certainly have exceeded that of the Earth's present orbit — say, 200,000,000 miles—its period of rotation must also have been greater than that of the Earth's revolution, which is 365 days. This is gathered up into a globular mass, and in turn throws off a ring, which in time becomes what is known to us as the Moon. The Earth's mass at this time must have been somewhat greater than the diameter of the Moon's orbit—say 500,000 miles, its rotation must have occupied more than 29 days, which is the moon's present period of revolution. From that time to the present, it has shrunk to its present diameter of 8000 miles, and revolves in about 24 hours. It will be understood from this that those planets that are outside the Earth are older than it; those within, that is, Mercury and Venus, are newer. They are older, or younger, as regards their existence as planets, but the matter of which the whole is composed once formed part of the Sun's mass.

Much has been said and written as to the changes of temperature the Earth has undergone. Precession of the Equinoxes, Evagation of the poles, the Gulf stream, &c., have been invoked to account for this. But whatever may be said, the whole must ultimately resolve itself into a question of distribution of land and water, and as this rests upon what I have been trying to account for, that is, alternation of sea and land, it is in reality but one question.

There is another matter may be mentioned, in conclusion, which must have had a great influence on climate.

It follows as a necessary corollary from what has been said, that the Earth in course of its existence must have occupied every possible degree of inclination to the axis of its orbit; at present it is inclined at an angle of 23 deg. 28 min., but it is evident that before it attained to this that it must either have been more or less. No two planets are at the same angle. Venus is said to be inclined at an angle of 75 deg. Jupiter is but 3 deg., or nearly upright. Uranus is quite the reverse, its poles being nearly horizontal, or on a line with the plane in which it moves. Thus it would seem that none of these are fixtures. Their motion may be slow, but it is evident they do move, or they could never have been placed as we now see them, there being apparently no standard position of inclination; but the various phases they pass through must necessarily have a great influence on their temperature and climate, for instance, the Earth's inclination occasions its seasons, length of days, &c., but how different these phenomena must be on Jupiter. From its position nearly the whole of its surface must be exposed to the Sun in the course of ten hours, its days and nights but a few hours long, its climate a perpetual Spring. On Uranus, the very reverse of this must prevail, its climate must of necessity be the most extreme, such indeed as we can form no conception of; but if we think of the Earth as having been exposed to these extremes with every intermediate shade, and that many times in succession,we are in a measure prepared for meeting with Coal even on Melville Island. I may state that, in contradistinction to the present view, I have never met with a work treating of the physical history of the Earth, in which it is not assumed that the Earth has always had its present spheroidal form, and been in the same position it now occupies with respect to the Sun. This is in effect, as though it was taken for granted that the series of rocks forming the Earth's crust, had always been exactly as we now see them, instead of being, as they are known to be, a matter of evolution.

MARCH 14TH, 1871.

THE VICE-PRESIDENT, THOMAS J. MOORE, C.M.Z.S.L., in the Chair.

MR. MORTON, F.G.S., read several letters descriptive of the Stone-quarry which was formerly worked in the Lower Keuper Sandstone of Rathbone Street, at the corner of Washington Street. The stone, including the monolithic columns of Great George Street Chapel, was obtained there in the year 1840.

The following communications were read:—

THE CHEMISTRY OF LIMESTONES AS ILLUSTRATIVE OF THEIR ORIGIN—

With Experiments.

BY A. NORMAN TATE, F.C.S.

ON PROBOSCIDEAN REMAINS IN THE FREE MUSEUM OF LIVERPOOL. PART I.

BY THOMAS J. MOORE, C.M.Z.S.L.

APRIL 11TH, 1871.

THE PRESIDENT, CHARLES RICKETTS, M.D., F.G.S., in the Chair.

MR. MORTON, F.G.S., announced the discovery of annelid barrows in the upper beds of the Keuper Sandstone, immediately under the Conglomerate-bed in the railway section near the village of Orrell, Seaforth, near Liverpool. He also exhibited a section of the strata exposed there.

The following communications were read:—

EFFECT PRODUCED BY RED SANDSTONE UPON SALT WATER.

By Isaac Roberts, F.G.S.

In the last Session of this Society, I read a paper on "The Wells and Water of Liverpool," the purport of which was to show in what way the water flowed through the sandstone rocks in this neighbourhood, and the effect produced on the water in its passage through them.

I attempted to prove that the large supply of water which is obtained from deep wells in different parts of the town has its source in the sea, and that the sea water is deprived of most of its salts by the mechanical or chemical action of the sandstone rock through which it filters.

In the paper referred to I gave the analyses of the waters obtained from several wells in this neighbourhood, to show that the quantity of the salts held in solution varied in amount in proportion to the age of the wells respectively, to the quantity of water that had been pumped out of them, and to their distance from the docks or the River Mersey; and I showed inferentially that the quantity of water which could be obtained from the sandstone rock was practically inexhaustible, but with time and continuous pumping it would gradually become more and more brackish, until it would approximate the salinity of sea water.

I give the following additional evidence in confirmation of this theory:—

One of the wells to which I particularly referred in my former paper is situate in Rainford Square, distant about 500 yards from the river, and it is 76 feet in depth below high water mark of spring tides. In the month of March, 1867, the water was analyzed for me by E. Davies, F.C.S., and again in the month of February this year, it was analyzed by the same chemist. The following are the analyses made in both years respectively:—

	GRAINS PER GALLON IN 1867.	GRAINS PER GALLON IN 1871.
Chloride of Sodium	Enormous	138.44
Ditto Magnesium	Large	49.01
Ditto Calcium	Very large	51.45
Sulphate of Lime	Ditto	26.55
Ditto Magnesia	Small	None
Carbonate of Magnesia	Ditto	2.22
Ditto Lime	Large	8.68
Oxide of Iron	Ditto	Trace
Chloride of Potassium	Small	None
Total Grains per Gallon	.. ..	276.35
Residue actually obtained by evaporation	231.00	274.40
Hardness before boiling	150°	159°
Permanent hardness		143°
Trace of Nitrates and Oxide of Iron		
The quantity of Organic Matter is about	1.75	1.12

By comparing the above analyses, it will be observed that in the year 1867 the hardness of the water was 150°, but in February this year it was 159°, being an increase of 6 per cent. in the four years. In the year 1867 the total quantity of salts held in solution was 231 grains per gallon, but this year it is 276.35 grs. per gallon, being an increase of about 19½ per cent. in the four years.

The quantity of water that has been pumped out of the well each year since 1867 is about 80 millions of gallons.

SECTIONS OF THE BOULDER-CLAY AT THE GAS WORKS, LINACRE, NEAR LIVERPOOL.

By Isaac Roberts, F.G.S.

Linacre Gas Works are situate about half a mile to the north of Bootle, and the following sections were obtained in the excavations for tanks for the gas holders and a well for water. The sections are within about fifty yards of each other in position.

Section First, in the South Tanks:—

Vegetable soil	1 foot.
Sand, with marsh plants and roots	7 feet.
Boulder-clay	14 „
Coarse yellow sand and gravel, with great numbers of shells of Turritella communis	3 „
Boulder-clay	16 „
Coarse gravel	2 „
Red Bunter Sandstone at	43 feet.

Section Second, in the Water Well:—

Vegetable soil	1 foot.
Sand, with marsh plants and roots	9 feet.
Boulder-clay	21 „
Gravel and sand	1½ „
Boulder-clay	6 „
Red Bunter Sandstone at	38½ feet.

SECTION THIRD, IN THE NORTH TANKS:—

Vegetable soil	2	feet.
Sand, with marsh plants and roots	4½	,,
Boulder-clay	11	,,
Sandy clay seam	1½	,,
Boulder-clay	22½	,,
Red Bunter Sandstone at	41½	feet.

The surface of the ground to which these sections refer is about fifty feet above the level of the Old Dock Sill.

The following species of Mollusca* were found in the upper bed of Boulder-clay, or that which underlies the bed of sand containing the marsh-plants, roots, &c., and above the sandy clay seam in the north tanks:—

Turritella communis.—*Linn.*—Great numbers.
Cyprina Islandica.—*Linn.*—Many.
Fusus Islandicus.—One.
Aporrhais pes-pelicani.—*Linn.*—One.
Trophon clathratus.—*Linn.*—Two.
Tellina solidula *pult.*—Several.
Natica.—One.
Nasa reticulata.—*Linn.*—Several.
Purpura lapillus.—*Linn.*—Several.
Cardium edule.—*Linn.*—Many.
,, echinatum.—*Linn.*—Many.
Ostrea—a fragment.—*Linn.*—One.
Pecten opercularis.—*Linn.*—One.

Other shells, in a state too fragmentary to be determined, were also found.

In the bed of Boulder-clay which *underlies* the sandy clay seam, the following shells have been found:—

Turritella communis.—Great many.
Cyprina Islandica.—Many.

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* Named by Mr. F. P. Marrat, of the Derby Museum.

Tellina solidula *pult.*

Cardium edule.—Many.

Purpura lapillus.—Several.

Littorina littorea.—*Linn.*—Two.

Lutraria.—A fragment.

Mactra.—Two.

Buccinum undatum.—*Linn.*—One.

Dentalium entalis.—Fragments.

Fossil Cardinia, and part of the stem of an encrinite, probably drifted from the Mountain Limestone.

There are no shells in the sand which overlies the Boulder-clay. This sand (about eight feet in thickness) appears to be the ordinary blown sand, such as is seen on the shores of the River Mersey at the present day.

Many of the shells of the Turritella are perforated by one or more very small round holes, which appear to have been made to get at the living mollusca. The Turritella shells are by far the most numerous found, and the words "one," "two," "several," "many," &c., indicate the relative numbers of the other shells. After washing the shells in distilled water and then analyzing it, I found it contained a large quantity of sulphate of lime.

The two beds of clay, with the intervening seam of sand, contain great numbers of Boulders, which vary from the size of small gravel up to three feet in diameter, and many of them are flattened on one side and scratched. The lower bed of clay is more compact, and contains a larger number of stones, than the upper bed. The clay of the upper bed is friable and readily falls to pieces, but the lower clay possesses great tenacity, and has more limestone in it than the upper clay.

It is seldom that a section through the drift down to the rock is seen in the neighbourhood here referred to. The drift, it will be observed by referring to the sections, is upwards of forty feet in thickness, and the surface of the *rock* is about nine feet above the Old Dock Sill.

ON SOME SPECIMENS, SUPPOSED TO BE FOSSILS OF A PLANT NAMED PYCNOPHYLLUM (Brongniart and Schimper); FLABELLARIA (Sternberg); NŒGGERATHIA (Nonnul); CORDAITES (Unger and Dawson); IN THE RAVENHEAD COLLECTION OF FOSSILS, FREE PUBLIC MUSEUM, LIVERPOOL.

By the Rev. Henry H. Higgins.

The geological position of the plant remains which I am about to describe is very definitely ascertained. It is in the upper part of the middle Coal-measures, between the Coal seams known as the Ravenhead and the Pigeon-house coals of the St. Helens Coal-field. In the "Geological Memoirs" this interval is estimated at 271 feet perpendicular thickness, consisting of grey, white, and ferruginous sandstones. Bluish shales occur at each end in the vicinity of the Coal-seams. The beds have been exposed by an open railway cutting, which has been driven through a hill lying to the east of the Ravenhead Plate-glass Works, the excavation being in one place about sixty feet in depth. The line of rails crosses the strike of the strata obliquely, so that the horizontal distance between the Ravenhead and the Pigeon-house coals is extended to about 400 yards. There is apparently no fault or important dislocation through the whole of the distance: practically, therefore, the excavation gives a section of the strata between the two Coal-seams, on a magnified scale of about 4½ diameters.

Little attention seems to have been given by British Palæontologists to the plant which forms the subject of this paper. M. Schimper describes four species of the genus, the type of which is *Pycnophyllum borassifolium* of Brongniart. The former author, recording the occurrence of *Pycnophyllum* in the coal shales of Bohemia, remarks that it probably pertains to most of the formations of the same epoch throughout Europe. Dr. Dawson, in his account of the coal formations of Nova Scotia and New Brunswick, observes respecting *Cordaites* or *Pycnophyllum*:—"This plant is represented in the coal formation chiefly by its broad, striated leaves, which are extremely abundant in the coal and its associated shales. Some thin coals are, indeed, almost entirely composed of them." "It is extremely rare to find the leaves attached to the trunk; they are commonly found dispersed and mixed up with other organic remains; very seldom (almost never) entire, but easily recognisable by their strap-like form, which resembles that of the leaves of Yucca; by their shining surface, traversed by slender nervures parallel and simple; and lastly by their substance, in which they resemble the thick and coriaceous leaflets of Zamia and Ceratozamia" (Schimper.) Not more than two good specimens of the leaves occurred at Ravenhead, one of them in ironstone, fourteen inches in length, and with the apex perfect; but their remains were abundant in the shales, and by no means rare in the sandstones, where they formed patches of black epidermal tissue, which on examination proved to be, not a confused, matted layer, but a regularly veined, thin, carbonaceous covering, evidently the remains of a single leaf. Judging from the ironstone example found at Ravenhead, a specimen which I saw in the museum at Manchester, must originally have been fully four feet in length. Taking into consideration the large size of the leaf, together with its simple parallel striation and the absence of a midrib, it seems probable that *Pycnophyllum* was very different in form from any other plant at present recognised as pertaining to the middle Coal-measures.

In the course of more than ten months, during which my visits were paid to the cutting very frequently, some scores of plant impressions were observed, chiefly amongst the sandstone beds, unlike those of any other fossil vegetable, and having characters sufficiently pronounced to be distinguishable, even in a very fragmentary condition. The distinctive marks were chiefly simple longitudinal rounded plications, following no regular pattern, but flexuous, and often overlapping each other. A specimen was at length obtained in which these plications partially surrounded a sub-conical fossil, apparently the lower extremity of a stem, or a portion of the stock or base of a large tuft of leaf-stalks. Compared with the various Lepidodendroid stems which abounded in the cutting, the herbaceous character of this fossil was conspicuous; and I think it may have been a vestige of *Pycnophyllum*.

Manifestly belonging to the same plant with the above-described specimen, occurred many fossil stems, of which the largest was nearly cylindrical, more than a yard in length, and four inches in diameter. None of them showed any tendency to divide into branches. The most remarkable feature in these stems is the presence of small oval scars, slightly concave at the centre and tumid in the form of two slender crescents towards the circumference. The scars are arranged spirally and quincuncially at somewhat distant intervals, and leading to each scar are three or four sharply-defined raised lines, parallel to the axis of the stem and visible for several inches upon its otherwise smooth surface. It seems probable that these lines indicate the course of vascular ducts, designed for the supply of the vegetable appendage borne by the scar; in which case it may be inferred that the stem was more or less succulent, and that the vascular ducts resisted pressure more effectually than the tissue in which they were embedded.

A specimen of the *supposed* stock of *Pyncophyllum* in the Ravenhead collection encloses a *Sternbergia.* This may have been accidental, but I have reason to believe that it was by no means a solitary example; for several large specimens of *Sternbergia* exhibit on their surfaces an arrangement exactly corresponding with that of the scars and ducts above described as occurring on the stems of *Pycnophyllum*, except that at the scars the rings of the *Sternbergia* become prominent and almost nodulous. A similar fossil has been figured by Artis in his "Antediluvian Phytology," plate viii, where to the name *Sternbergia transversa* he appends the following description:—"Stem with double longtitudinal keels terminating at different heights spirally round the stem, and furnished at their termination with small tubercles. Count Sternberg has figured a small specimen of a plant of this kind in his 17th plate. He considers it to have some resemblance to the recent genus, *Yucca*, or perhaps *Pandanus*."

The Ravenhead examples of *Sternbergia*, supposed to be connected with *Pycnophyllum*, are very unlike the fossils figured by Lindley and Hutton as *Sternbergia approximata*, which are now said to be casts of the medullary cavity of *Dadoxylon*. Of these many.specimens occurred at Ravenhead, one of them enclosed in the ligneous portion of the stem.

The reproductive raceme *Antholites*, Lindley and Hutton, was also found in the same locality, but of smaller size than a magnificent specimen in the museum at Manchester, labelled in the handwriting of Dr. Dawson *Pycnophyllum borassifolium*.

Such are some of the materials on which I venture to offer a suggestion to the probable form of *Pycnophyllum*. Dr. Dawson states that the leaves of *Pyncophyllum* are exceedingly abundant; whilst on the other hand the stems are very rare. Now, if the leaves were borne on

J. C

the summit of the stem, this disparity seems improbable. I conclude, therefore, that the leaves, as in *Yucca*, grew in large tufts on a stock or very short stem, and that the tall unbranched fruit-bearing stem was produced comparatively rarely and only under peculiarly favourable circumstances.

The small, distant, oval scars, with their long trains of ducts, could hardly have been the vestiges of petioles at all, much less of the stalks of such leaves as those of *Pycnophyllum*, but correspond well with the support of peduncles bearing reproductive organs in racemes. Such an appendage is met with in *Antholites*, asserted on high authority to belong to *Pycnophyllum*.

I am unable to throw the least light on the structure of *Antholites*, but amongst the Ravenhead fossils are specimens exhibiting four or five *Volkmannia* spikes on a single, apparently leafless, stem.

The accompanying plate represents the scars and ducts as seen on a compressed stem four inches in diameter. These markings, which are more sharply defined on some of the smaller stems, become less distinct as the specimens exhibit more of the *Sternbergia* character.

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OF THE

PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION THE THIRTEENTH,

1871-72.

(The Authors having revised their own papers, are alone responsible for the facts and opinions expressed in them.)

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ABSTRACT OF THE PROCEEDINGS
OF THE
LIVERPOOL GEOLOGICAL SOCIETY.

SESSION THIRTEENTH.

OCTOBER 10TH, 1871.

Anniversary Address by the President, CHARLES RICKETTS, M.D., F.G.S.

GENTLEMEN,

IT was remarked by that excellent geologist and acute observer, Sir Henry de la Beche, that it is no reflection on the abilities of those who have paved the way for so much that is known, that they indulged in speculations which at present seem somewhat extravagant; they merely worked with the knowledge of the day, as we do now, and the results are different, merely because that knowledge is different. In the same way, we have every reason to believe that existing information will be greatly inferior to that of a century hence, and consequently that many views now current will be abandoned.* In such a spirit (so far as I am able, with the limited number of books and essays which have been available), I will endeavour to enter upon a consideration of the opinions that have been held from time to time by different authors upon the subject of denudation, and especially on the formation of valleys, respecting which the most diverse theories have been advanced; and I must claim from you that the same indulgence may be accorded to myself when, in my interpretation of facts, I arrive at conclusions differing from those who are masters in our science.

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* Report on the Geology of Cornwall, &c. 1839, p. 349.

The majority of geological formations have certainly been deposited in what was, at their respective periods, the sea; it is therefore not a matter of surprise that the origin of these deposits has been so generally attributed to the erosion of coast lines, especially when we consider that "in the crash of a heavy Atlantic wave when it strikes the coast, the blow is so great that the rock seems to tremble beneath the feet;" and when we observe the amount of abrading action which is going on along our shores, more especially among the more easily disintegrated strata of the south and east of England, where large masses of material are carried away during every storm, whilst the less palpable but constant action of subaërial agencies in disintegrating and denuding far more extensive areas has been comparatively overlooked. But, unless we suppose that the medium elevation of the land was in Palæozoic times situated very much higher above the sea level than are our present continents, the average of which has been calculated by Humboldt at about 925 feet, it appears impossible to attribute the origin of these formations, amounting sometimes to several miles in thickness, to the action of breakers upon sea-cliffs, with the exception of a comparatively thin stratum situated at their base.

In determining the source whence the deposits entering into the composition of Palæozoic rocks have been derived, attention must be directed to the frequent recurrence, at or near the base of these formations, of evidences of deposition in shallow water, such as ripple-marks, sun-cracks, tracks of annelids, &c., current bedded strata, and conglomerates, whilst an accumulation of materials has subsequently occurred, amounting, it may be, to several miles in thickness; proving that, simultaneously with the deposit, subsidence of the land has taken place to at least as great an extent as the whole thickness of the superincumbent strata. It therefore follows that if the then contour of the land was similar to the present, though the beds at the base may at their formation have been situated near the shore-margin, those overlying them, but separated by this great thickness of strata, must, in consequence of the subsidence, have been deposited at a distance of many miles from the coast, so far that by no possibility could the sediment have been derived from marine denudation acting on cliffs. Much less will this appear probable if the altitude of ancient cliffs was in proportion similar to those now existing, the medium height of which has been estimated by Mr. Croll at twenty-five feet.

Mr. A. Geikie, local director of the Geological Survey of Scotland, in a paper read before the Geological Society of Glasgow, in 1868, has shown how insignificant is the sum total of the waste along the sea-margin of the land by all that is usually included under marine denudation, compared with that effected by the meteoric agents in the interior; that, calculating the amount of erosion of land surfaces at the rate of the 6,000th of a foot per annum, in accordance with careful investigations which have been made respecting that of the basin of the Mississippi, it would take 6,000 years to lower a given area one foot; and therefore as according to Humboldt the average height of the European continent is 671 feet, it would be entirely removed by subaërial denudation alone in little more than four millions of years; whereas, supposing the sea to eat away a continent at the average rate of ten feet in a century, which Professor Geikie thinks is a high estimate, it would, in the same length of time, have been able to remove a mere marginal strip of land between 70 and 80 miles in breadth only. That, even in an island like Britain, the extent of surface exposed to the power of the waves is small indeed when contrasted with that which is under the influence of atmospheric waste, and that of course in the case of continents the discrepancy is infinitely greater.*

This and other papers attracted to this subject an amount of attention which was greatly required, though Sir Charles Lyell had shown many years previously that the action of waves and currents on sea-cliffs, or their power to remove matter from above to below the sea level, is insignificant in comparison with the power of rivers to perform the same task, because the operations of the ocean are limited to a single line of cliff surrounding a large area, whereas great rivers with their tributaries act simultaneously on a length of bank almost indefinite. He calculates that the amount of solid matter carried down to the Bay of Bengal by the Ganges and Brahmapootra united would, to produce the same effect, require a wasting coast like that of Holderness, nearly 28,000 miles in length, or considerably longer than the entire circumference of the globe.†

As indicating the opinions of the ancients, and especially of Pythagoras, upon the manner in which valleys have been formed, the words of Ovid have often been quoted:—" * * * *quodque fuit campus, vallem decursus aquarum fecit.*"

But, though this doctrine has been taught by many, we will pass over their names, and commence with Dr.

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* On denudation now in progress. *Geological Magazine*, 1868, p. 249.

† Lyell's "Principles of Geology," chap. xxi.

Hutton (1788) who held similar views. I quote Mr., now Professor Phillips, in saying, that, in opposition to Werner and most of the moderns, who consider the phenomena which have been unfolded by geological research, as the effects of causes no longer in action, Hutton believed that all the revolutions which have visited the earth were but the result of the ordinary operations of nature, continued through very long periods of time. He was of opinion that what is now sea, was formerly dry land; and that, by the action of rain and rivers, materials are accumulated on the bed of the sea to produce the strata of new continents, which by some convulsion, like many that have happened before, will be uplifted and laid bare; whilst that part of the earth which we inhabit will be sunk under the new ocean. He likewise maintained that valleys were in all cases scooped out by the streams that run in them.*

It is probable that Phillips was only expressing the opinions then prevalent when, in the "Geology of Yorkshire" (1829), he objected to the hypothesis or theory of Hutton as being wholly inadmissible, on the grounds that it ascribes to the ordinary efforts of nature effects which appear much beyond their power, and as clashing with what he *then* considered plain facts; that it was inapplicable to the numerous valleys in the chalk districts, which, from the absorbent nature of the strata, have never carried water. He at that time conceived that the excavation of valleys can be ascribed to no other cause than a great flood of water, which overtopped the hills from whose summits those valleys descend;† being evidently influenced in this idea by the opinion, then so general, that the origin of the present condition of the world must accord with that of the Mosaic chronology, and therefore, as the excavation of valleys could not have taken place by ordinary causes within a limited period, he attributed their production to the Noachan deluge.

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* "Geology of Yorkshire," pp. 22, 23.

† Page 22.

This diluvial theory does not appear to have been long retained. The same author in 1853 gave it as an axiom that rivers run in valleys which the sea made for them;* an hypothesis which has found favour with many geologists up to the present time, though no sufficient explanation has been offered to account for the redistribution of the abraded rocks, and though it appears to be entirely at variance with the ordinary effects of marine denudation. The action of waves and tides can only widen the margin of a bay or of an estuary when once it has been formed by some other agency, but will have at least very little, even if it has any, power to deepen it; for the materials derived from the denudation of the cliffs, or brought down by streams, protect its bed from further abrasion. The effect of tidal action is to carry up sand, mud, and other *débris* with the water into indentations along the coast, however produced; and, if there is no rush of back water, a considerable amount will be left behind after every tide, and thus gradually fill up the harbour. We have an example of its occurrence in the Low-water Basin of the Birkenhead Docks, which, in consequence of the discontinuance of sluicing operations, very soon became silted up to about the level of low-water mark; also in the sands and other accumulations which occur in the numerous coves and havens around our coasts. Again, access to the ports of Chester and Lancaster has for some time been greatly obstructed, in consequence of the filling up of the estuaries of the Dee and Lune. This has been in a great measure caused, and certainly much hastened, by the construction many years ago of weirs, which prevent the rush of back water, and by the reclaiming of land on their shore margins, contracting the tidal area, and thus diminishing the scour. On the coast of Dorsetshire, where marine denudation is excessive, and the beach is formed of a large accumulation of pebbles and gravel, many of the small rivers are completely blocked up, so that their waters have to percolate through banks of shingle. In the case of somewhat larger rivers, where the neighbouring cliffs consist of loose materials, similar to those of a great portion of the southern and eastern coasts, this tendency which the sea has to form banks across their embouchures, has resulted in the formation of tongues or spits of sand and shingle extending sometimes for several miles, and deflecting the course of the river in the direction of the current of the flowing tide. Such has occurred in the case of the Yare, which must formerly have emptied itself close to Yarmouth; but its course has been altered by the accumulation of sand-dunes on its northern bank, so that its present mouth is situated four miles further south. The ancient mouth of the Alde, there can be but little doubt, was situated at Aldborough, but the river now passes for a distance of ten miles within a bank of shingle before it empties itself into the German Ocean. Professor Geikie remarks that nearly the whole of the firths on the eastern sea-board of the Highlands of Scotland are conspicuous for the sand-bars at their mouth, which have been thrown up by the tides above high-water mark, and run out from either bank, striving as it were to form a complete barrier against the sea outside. * Even in the Bay of Fundy, with its tremendous bore and fifty-feet tide, extensive mud-flats are, according to Sir Charles Lyell, now being deposited; so that, instead of denudation, accumulation is taking place on its bed.

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* Phillips' "Rivers, Mountains, and Sea Coast of Yorkshire," p. 9.

Sir Roderick Murchison, as President of the Royal Geographical Society, in his anniversary address in 1864,

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* "Scenery and Geology of Scotland," p. 130.

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OF THE

PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION THE THIRTEENTH,

1871-72.

(The Authors having revised their own papers, are alone responsible for the facts and opinions expressed in them.)

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IT was remarked by that excellent geologist and acute observer, Sir Henry de la Beche, that it is no reflection on the abilities of those who have paved the way for so much that is known, that they indulged in speculations which at present seem somewhat extravagant; they merely worked with the knowledge of the day, as we do now, and the results are different, merely because that knowledge is different. In the same way, we have every reason to believe that existing information will be greatly inferior to that of a century hence, and consequently that many views now current will be abandoned.* In such a spirit (so far as I am able, with the limited number of books and essays which have been available), I will endeavour to enter upon a consideration of the opinions that have been held from

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* Report on the Geology of Cornwall, &c. 1839, p. 349.

Dr. Newberry, Geologist to the United States' expedition to the Colorado River in the beginning of 1858, has formed a very different opinion; at least, respecting the formation of that, the most wonderful of all rivers. He states that the mode of origin of its peculiar valleys and ravines (called canons) is quite simple; the stream which flows at the base of almost perpendicular banks, from 3,000 to 6,000 feet, that is considerably more than a mile below the surface, being the most magnificent gorge as well as the grandest geological section of which we have any knowledge, has, since the dawn of the present geological epoch, been cut down by the rapid current through all the sedimentary strata, and several hundred feet into the Granite base on which they rest. The accounts we have had respecting this most remarkable river have received but little attention from English geologists; it has been to me a matter of surprise that none of the writers who took part in the discussion in the *Geological Magazine* have made allusion to this, the most extraordinary example which exists in proof of the subaërial formation of valleys. I conclude that Colonel Greenwood can never have perused the account of the expedition, or he would not have neglected to bring forward evidence so strikingly confirmatory of what has been called his "hard gorge and soft valley theory,"—that wherever "there are alternations of hard and soft strata in the course of a river or valley, so sure will there be alternations of gorge and alluvial flat."

If Dr. Newberry's opinion of the long-continued elevation of the Colorado plateau above the sea-level requires confirmation, it has been afforded by Professor O. C. Marsh, of New Haven, Conn., U.S., who has lately made an extensive tour in the Rocky Mountain region. An expedition last year along the main tributaries of the Colorado

River in Utah proved the district to be a Miocene country, in other words, a fresh-water Tertiary formation, formerly an enormous lake, abounding in crocodiles, serpents, turtles, and fishes. Rhinoceroses and various other mammals of the warmer regions seem to have frequented the shores of this ancient fresh-water lake.*

The eroding power of ice in the shape of glaciers has long been known to have had a great effect in excavating valleys, and causing denudation on lofty mountains, and in Arctic regions, but it is only of late years that it has been almost universally conceded by geologists, that this glaciation has formerly extended over districts very much farther south, and in mountains to a far lower level than glaciers do at the present time. In the North American continent, as far south as 38° or 40° north latitude, almost everywhere, upon the drift being removed, the solid rock beneath is smoothed and polished, and covered with grooves and striations, similar to those which occur amongst the glaciers of the Alps. It was in 1840 that Agassiz, extending his views respecting glaciers, concluded that a large portion at least of the British Islands had been covered with a universal coating of ice, probably as thick as that in the north of Greenland at the present day. While this large glaciation was going on, a slow submersion of the land took place; and as it sank the glaciers descending to the level of the sea deposited their moraine rubbish there. Gradually the land sunk more and more, the cold still continuing, till this country, previously united to the Continent of Europe, became a group of icy islands still covered with snow and small glaciers.† The effects of this glaciation can be seen very generally in North Wales, and also in many other parts of the British Isles. In our own neighbourhood, the Triassic rocks on each side of the valley of the Mersey have been discovered by our Secretary, Mr. Morton,* and others, to be extensively smoothed, grooved, and striated by this glacial action, these markings, in a comparatively soft sandstone, having been preserved by the deposition of materials (sand and the Boulder Clay) resulting from the grinding motion of the glaciers which, in a similar manner to what is described by Dr. Robert Brown as now occurring in Greenland, issued as subglacial rivers thickly loaded with mud, and flowing into the sea, discoloured the water for miles, being eventually deposited on the bottom as a thick coating of clay,† amongst which have been scattered ice-marked and other boulders, which have drifted in bergs or coast-ice from Cumberland, Wales, and Ireland.

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* *Geological Magazine*, 1871, p. 127.

† Ramsay's "Physical Geology and Geography of Great Britain," p. 78 to 80.

I would ascribe the subsidence of the land, both here and in other parts of England, during this Glacial period, to the combined weight of ice and the Boulder Clay pressing down the surface to below the sea level; the land being again raised to a considerable extent, when, upon the return of a more genial climate, it was relieved of its load of ice and snow.

The origin of certain rock basins, now holding lakes on the watersheds, and in the old glacier-valleys of North Wales and Switzerland, was attributed by Professor Ramsay in *Ancient Glaciers of North Wales* (1859) to the action of ice, and he has given, in a paper read before the Geological Society in 1862, a fuller exposition of his views; he considers that it is impossible for them to have been produced by special subsidences or gaping fractures, for them to be simple synclinal basins, or that they lie in hollows of common watery erosion, but that in ice we have a power on account of the great size of the ancient glaciers capable of exercising such an erosive agency as to excavate these basins. It required a solid body grinding steadily and powerfully in direct contact with and across the rocks to scoop out these deep hollows, the situations of which may have been determined by unequal hardness of the rocks, by extra weight of ice in special places, or by certain accidental circumstances the clue to which is lost.*

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* *Quart. Jour.*, Geological Society, Vol. XVIII, p. 377.

† *Quart. Jour.*, Geological Society, Vol. XXVI, p. 682.

Though the contour of the British Islands has to a considerable extent been determined by glacial action, a large amount of subaërial denudation can be proved to have occurred subsequently, which, though it has caused, as Mr. James Geikie expresses it, "the finer touches of the great ice-chisel to be oftentimes wanting, its broad effects will be there, reminding one of those ancient sculptures from which the hand of time has effaced the delicate finish, but has been powerless to destroy the design." He has particularly alluded to the gorge through which the river Doon, in Ayrshire, makes its way after escaping from its parent lake, in which at least 70 millions of cubic feet of rock have been removed bodily by the stream in Post-Glacial times.† To take an example nearer home; the amount of Post-Glacial erosion in the Bala district might, to a considerable extent, be calculated from the accumulation of soil which exists wherever streams empty themselves into the lake; by the alluvial plain which fills up an ancient lake situated between Llandrillo, Cynwyd, and Corwen (for the presence of alluvium in the bottom of a valley is *primâ facie* evidence that the valley has by some cause been previously excavated to a greater depth); whilst stratified beds of loose gravel and sand, sometimes obliquely laminated, situated along the sides of the valley at varying heights, being 29 feet above the waters of the lake at Bala, 36 feet above those of the Dee at Cynwyd, and, judging partly from measurement and partly from calculation, about 50 feet above the river at Corwen,[*] indicate that not only the surface of the water, but also an alluvial plain, was at one period situated at these heights, and that barriers of Wenlock Rock at the foot of Bala Lake and at Corwen have been subsequently excavated to that extent.

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* *Quart. Journ.*, Geological Society, Vol. XVIII, p. 185.

† *Geological Magazine*, 1868, p. 19.

Though there has been so great a diversity of opinion respecting the powers by which the excavation of valleys has been accomplished, it had by no means escaped the notice of observers that subaërial agencies have had a great effect in causing the disintegration of rocks. Thus Phillips, even when attributing the formation of valleys to marine action, states that the atmosphere produces further waste, carbonic acid eats away the limestone, moisture softens and crumbles the shales, rains wash away the loosened grains of every kind, rills collect and rivers carry away the accumulated *débris*, and the rough old *sea* channels are in some places filled up with these deposits; in others, worn still deeper, are changed into those smooth dales or picturesque glens which are the boast and charm of the North.[†] Geologists formerly considered that these meteoric causes alone were too insignificant to have been able to produce the great changes on the earth's surface, by which the enormous thicknesses of rock have been removed, which must at some period have been situated in what are now extensive valleys, nor could they allow that great extension of time which is requisite for such a solution of the problem; and possibly they also found a difficulty in accounting for the redistribution of the disintegrated materials.

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[*] I am indebted to Mr. J. Parrott, of Llantysilio, near Llangollen, for these measurements.

[†] "Rivers, Mountains, and Sea-Coast of Yorkshire," p. 8.

Respecting the formation of Deltas and alluvial plains there appears to have been no difference in opinion, all considering them a deposit which has been brought down by rivers, either in mechanical suspension when in minute division, such as mud or silt, or if of larger materials, as sand and pebbles, that they have been pushed forward along the bed of the river by the power of the running water, until on the force of the stream becoming checked near its junction with the waters of a lake, or of the sea, opportunity is given for the subsidence and accumulation of the detrital matter; these deltas often extending backwards as alluvial plains for great distances up the valleys, as, for example, in that of the Mississippi to above its junction with the Ohio, the rise in this distance being so gradual that the river is there situated at a height of 200 feet only above the level of the Mexican Gulf. Though by far the greater amount of the sediment which forms alluvial plains will have been brought down by rivers, a portion situated at the margins will consist of detritus derived from the sides of the valley where it is deposited.

Even from the time of Herodotus has the theory been accepted that the origin of deltas is due to the accumulation of materials which have been brought down by rivers. He truly remarked that Egypt is the gift of the Nile, and after the lapse of many centuries this opinion is confirmed by the researches of modern explorers, especially by Sir Samuel W. Baker, who has proved that the fertilising mud, which at the periods of inundation is spread over the alluvial plain of the Delta, has been derived from the disintegration of rocks forming the mountains of Abyssinia, and has been brought down by the Blue Nile and the Atbara when swollen with periodical rains. The great historian imagined that the lower division of the country was formerly a deep sea, and that it had gradually been filled up by the deposition from the river; and by many geologists, if not by the majority, it is considered that under such circumstances deltal accumulations usually occur. But we have previously remarked that the presence of this sediment is indicative of a former denudation, however that has been accomplished; but the large amount and the nature of the accumulation would probably not have been conceived had it not been for Artesian borings which have been made in several localities; in the case of the Po to 400 feet and in that of the Ganges, near Calcutta, to 481 feet, in both cases passing through deposits of a fluviatile or terrestrial character, and piercing, even near the lowest depths which have been reached, beds of turf and vegetable matter; also in that of the Mississippi, near New Orleans, to 630 feet, through strata sometimes fluviatile, at other times containing marine and estuarian shells of species now living in the Gulf of Mexico; but in no instance was the base reached on which the alluvium rests.*

These accumulations necessarily imply a previous excavation, and as they so constantly occur at the mouths of large rivers, we are, I conceive, compelled to consider, having these examples before us, that, even without such borings, wherever they are situated near the sea, the deposition must likewise have been accompanied by a considerable subsidence, a rough estimate of the amount of which, and of the thickness of the alluvial deposit, might be calculated according to the breadth of the plain, to where the subjacent strata crop out on either side, and by considering the angle at which the valley would probably have been excavated in that locality prior to the commencement of this sedimentary accumulation, in accordance with the relative hardness of the strata forming the sides of the valley.

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* "Principles of Geology," Chap. XVIII and XIX. Sir C. Lyell states that there is now reason to suppose that the thickness of sediment in the delta of the Mississippi is probably as much as 1500 feet. *Q. J. G. S.*, Vol. XXV, p. 11.

An alluvial plain being situated in an extension of a valley, and as a delta is but an extension of the plain, being also situated in what is a continuation of the same valley, it follows that the area in which the delta accumulation occurs has, prior to its deposition, been excavated by the same causes which have excavated the valley, and these have been shown to be subaërial.

As deltas or other evidences of subsidence occur so generally near the mouths of large rivers wherever there is any great amount of sedimentary matter brought down by the streams, it appears impossible not to consider that the depression is dependent upon and caused by the accumulation; that as layer after layer of mud and sand has been deposited in these deltas and in the neighbouring seas, the constant addition of fresh material causes by its weight a subsidence which is generally gradual and imperceptible, but under certain conditions may occasionally occur suddenly. This opinion is, you are well aware, not a new one of mine, having been advocated for the first time before the Birkenhead Literary and Scientific Society, in 1865, when endeavouring to account for the immense accumulations of Cambrian strata which have been deposited in the Longmynd, Shropshire, to the amount of several miles in thickness, some of which bear conclusive evidences, such as impressions of rain drops, ripple marks, tracks of worms, &c., of having been formed in shallow water.* In a paper read before this Society in 1868, I directed your attention to the occurrence of ripple marks and other evidences of shallow water in the flagstones of Wenlock age in the Llangollen quarries, and the subsequent deposition upon them of an immense thickness of strata, attributing the formation of the accumulation to the continuous action of a great river, which, flowing from the north towards the south, brought down this muddy sediment, depositing it there, and also in Cumberland, in what was then a delta or estuary. (The Coniston flags and slates of Ribblesdale, Yorkshire, the only place in the lake district where I have examined rocks of the same age, were deposited under like conditions to those of Llangollen, being exactly identical in lithological structure, with similar calcareous concretions, and also containing the same fossils and having similar ripple marks.) Whilst the finer particles brought down by the waters of this "Wenlock" river and the lime held in solution were deposited at a distance from the current, and farther out at sea, as at Dudley, Wenlock, and Malvern. The occurrence of the subsidence I, explained as being produced by the weight of the materials deposited causing pressure on the crust of the earth, and consequently depression.

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* Proceedings, Birkenhead Literary and Scientific Society, 1864-65, p. 47.

It was not until some time had elapsed after advancing this theory, that alterations of the level of the surface of the land are in very many cases due to alterations in the amount of pressure, either from accumulations of material on, or otherwise from denudation of, the earth's surface, that I became aware of the late Sir John Herschel having advanced similar views. He states in "Physical Geography" (1862) that the tendency to continued elevation of the coast line of the Andes, and, indeed, of the whole continent of South America, on the one hand, and of depression over a large portion of the bed of the Pacific on the other, would naturally result from a change of the incidence of pressure on the general substratum of liquefied matter which supports the whole.* Or, as he has elsewhere expressed it when alluding to the same subject and the same locality, if the continents are lightened, they will rise; if the bed of the sea receives additional weight, it will sink.†

No one else, that I am aware of, has attributed the occurrence of oscillation of level in land surfaces to similar causes, with the exception of Principal Dawson, of Montreal, who, in the early part of this year, in giving a popular geological sketch of the Laurentian Period, stated that, at that time, the accumulation of sediment on the *still thin crust of the earth* weighed down the surface, and caused great masses of the sediment to come within the influence of the heated interior nucleus, and thus extensive metamorphism took place.‡

The formation of Bays has not unfrequently been attributed to the effects of waves and marine currents. To such causes has been assigned the production of the Bay of Bengal, or even that of the Gulf of Mexico, where such a theory presupposes, judging from the Admiralty chart, so great an erosive action as to have caused the excavation of the land to depths of from one to two miles, as well as the redistribution to some other locality of materials which have been removed. With much greater reason, Mrs. Somerville considers that the West Indian Archipelago may be regarded as the wreck of a submerged part of South America; that from the identity of the fossil remains of extinct quadrupeds there is every reason to believe that the rugged and tortuous isthmus of Central America and the serpentine chain of islands winding from Cumana to the Peninsula of Florida are but the scattered remains of an unbroken Continent.* Respecting the Bay of Bengal, the result of the artesian borings at Calcutta attests, according to Sir C. Lyell, what the "swatch of no ground" or "bottomless pit," situated at the distance of 30 or 40 miles from the margin of the delta, may also in all likelihood indicate, that the antagonistic force of subsidence has predominated for ages over the influx of fluviatile mud, preventing it from raising the plains of Bengal or from filling up a larger portion of the bay. A subsidence not exceeding two feet three inches in a century would, he considers, far more than counterbalance all the efforts of the two mighty rivers to extend the limits of their delta.†

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* Section 132. † *Good Words*, 1863, p. 55.

‡ *Leisure Hour*, 1871, p. 119.

Upon the examination of a map it will be seen that, with but few exceptions, bays have rivers flowing into them, and appear as if they formed a continuation of the valleys, being wide in accordance with the width of the valleys; also, contrary to what would be expected, the water, at least sometimes if not always, becomes very rapidly deeper in those cases where the deltas are greatest and where the greatest amount of sediment is being deposited. To account for their production it will require the occurrence of a subsidence of the land to a greater extent than the valley can be filled up by the sediment brought down by the river. It is impossible for them to have originated from marine action, for the sea has but little power of erosion at a short distance below low water-mark, and therefore it is at the margins or coast lines only that marine denudation can take effect, and thus by the action of the tides and waves widen the area of bays still farther.

The formation and keeping open of large estuaries are considered by Lyell to be due to the *combined influence* of tidal currents and rivers. During the ascent of the tide a body of fresh water, flowing down in an opposite direction from the higher country, is arrested in its course for several hours, and thus a large lake of fresh and brackish water is accumulated, which when the sea ebbs is let loose as on the removal of an artificial sluice or dam. By the force of this retiring water the alluvial sediment both of the river and of the sea is swept away and transported to such a distance from the mouth of the estuary that a small part only can return with the next tide.* So far as the keeping open of estuaries is due to combined tidal and river action, I can fully agree with Sir Charles; but their formation must, I think, be attributed to quite different causes, as will be explained hereafter.

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* "Physical Geography," chap. x.

† "Principles," chap. xviii.

Colonel Greenwood will probably, upon reconsideration, see cause to alter, in a new edition of his work, the sentence in which he says that when rivers have estuaries instead of deltas it may possibly in some cases be owing as much to the rise of the land as to the wash of marine currents,† for this opinion is entirely at variance with what he writes subsequently—"Rivers can only cut valleys down to the level of the sea, and if the land is then *raised* the rivers may then deepen the valleys." ‡

An Estuary may be described as a bay situated in what has once been a narrow valley or gorge, and, like a bay, is the result of a subsidence of the land by which the river bed has been depressed below the sea level, so that the waters fill it up, in a similar manner to what occurs if an embankment is constructed across a similar narrow portion of a valley, with the addition of the changes which occur in the level of the water according to the state of the tide.

Taking as an example the estuary of the Mersey, it is evident that the agency by which it has been excavated has been sub-aërial. The smoothed, planed, and striated surfaces of the rocks which are to be found on each side of the valley beneath the Boulder Clay lead to the inference that the more ancient valley has to a great extent resulted from the eroding power of ice. As this Arctic temperature continued, the land subsided to a considerable extent below the present sea-level, and, whilst thus submerged, the sand, clay, and mud escaping from beneath the glaciers were spread over what had become the bed of an extensive ice-bound bay. Upon the climate changing and the glaciers becoming dissolved, the land relieved of its icy burden became raised considerably above its present level, and what is now our harbour was covered with a luxuriant vegetation, the river running through it probably as a narrow stream; but as sand and silt brought down by this and other rivers were deposited in the bay, and as the accumulation became greater, the influence of its pressure was extended more inland, so that the valley on being depressed, instead of conveying a small fresh-water stream, became the lateral boundaries of the present estuary. But so far is the bed of the Mersey from being deepened by marine action, excepting it may be at the narrower portion from opposite Seacombe to beyond Egremont, it is becoming filled up to a very considerable extent by the sand and silt brought down by the river and its tributaries, which have formed large banks in the upper reaches of the Mersey in consequence of the obstruction which the sea-water presents to its passage into the bay.

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* "Principles," chap. xxi.

† "Rains and Rivers," p. 80.

‡ Page 107.

The largest estuary in the world, that of the Colorado River, generally known as the Gulf of California, is a prolongation southward of the Valley of the Colorado, and appears as if situated in the channel through which the river at one time flowed, when at some far distant period it emptied itself into the Pacific Ocean 10° southward of its present mouth. It would require but a moderate subsidence of the land to cause a similar extension of the gulf northwards up the lower reaches of the Colorado River; and therefore I think we are almost compelled, at all events justified, in concluding that such a depression has already changed the southern extremity of the valley into the present estuary or gulf. Because the disintegration in width of the almost rainless district* through which the Colorado flows is shewn to have been very inconsiderable during an enormous lapse of time, it must not be inferred that a sufficient amount of *debris* is not brought down by it to account for its subsidence, as the result of the accumulation which is now in progress in the gulf, and is being washed forward by the tides to the coast of the Pacific; for Lieutenant Ives, the commander of the expedition, states that "even when the waters of the river are at the lowest they are of a dark red colour, and opaque from the quantity of mud held in suspension," this sediment having traversed its canons for hundreds of miles, it may be a thousand, with hardly any addition, the sediment having been derived from the Western flanks of the Rocky Mountains and from Utah.

There exists a difficulty in bringing forward many examples which would be considered decisive that the denudation of any great continent has been continuous, but we have, I think, such proof respecting those great tributaries of the Mississippi, the Missouri and the Arkansas, which have their origin on the eastern or opposite slopes of the Rocky Mountains to those in which the Colorado takes its rise. A perusal of the account of the United States expedition to the latter river will be conclusive that its deep and perpendicular gorges or canons, extending for so many hundreds of miles, could not have been submerged "since the time when the waters began to cut deeply into the solid Carboniferous limestones and sandstones which form the Colorado plateau," and therefore the land situated at the same height upon the opposite flanks of the mountains must also during the same time have been far above the sea level, and must likewise during the whole of this extended period have been exposed to denudation from atmospheric agencies alone.

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* The annual amount of rainfall at Fort Yuma is only 3.15 inches.

Though the climatic conditions have been formerly and are now greatly different on the two flanks of the Rocky Mountains, and therefore it must necessarily occur that there will be great differences in their physical aspect, still gorges have been excavated on their eastern sides which, both in extent and depth, would be considered enormous were they not so greatly surpassed by the canons of the Colorado. On the Canadian River there are canons at least 250 feet deep, extending for a distance of 50 miles and probably very much more; on the Red River of 70 miles in length, with escarpments from 500 to 800 feet high.

Though a large portion of the American Continent has been permanently raised above the sea-level during a porlonged geological period, such has been far from being the case with the whole. The valley or basin in which is now situated the alluvial plain of the Lower Mississippi, after having been excavated to an extent at least as great as that of the thickness through which the Artesian borings pierced (630 feet), and probably very considerably more, was subsequently depressed to 250 feet below the present level of the river, forming during a portion of the time an estuary in which was deposited a sediment containing marine shells, some of which are now peculiar to the Gulf of Mexico; whilst above the marine strata are situated beds now forming cliffs or bluffs composed of fluviatile origin, resembling the loess of the Rhine.* These fluvio-marine strata have, in consequence of upheaval to a considerable extent above their present level, been exposed to valley denudation prior to the deposition of the present delta.

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* Lyell, "Principles," chap. xviii. Foster, "Mississippi Valley."

There appear to be instances in which depression of land may be traced to the pressure of accumulations which have not been dependent on river action—at all events, not to so great an extent that they could have formed harbours such as those along the coast of Hampshire and Sussex, whose origin is considered to be chiefly due to submergence which, according to Mr. Godwin-Austen, there is reason to believe, has gone on till within the last few centuries. Taking for example that of Portsmouth, with which I am in some measure acquainted (and the others situated on the borders of the two counties cannot greatly differ from it), the amount of impalpable mud, derived from the disintegration of the Chalk and the Lower Tertiary Clays, brought down by the stream which empties itself into it, must be too insignificant in quantity to have produced so great an effect as to cause such subsidence; besides, on coming under the influence of the tides at the mouth of the harbour, it must necessarily be rapidly and extensively dispersed by the currents in the English Channel. At Spithead large accumulations of flinty shingle, gravel, and sand have been formed, the thickness of which is not known, but have been proved to be many times greater than the beds of superficial gravel along the coast from which they have been chiefly derived, being the *debris* of the easily disintegrated cliffs carried forward by the set of the tides and deposited there. That the accumulation is recent was rendered evident during the construction of the submarine foundations of the fortifications for the defence of Portsmouth, by finding the lower jaw of the Red-deer *(Cervus Elaphus,* Linn.*)*, retaining most of its animal matter, at a depth of 40 feet from the surface of the shoal.* Accumulations such as these, extending over a considerable area, would, I think, be amply sufficient to account for that depression of the land upon which the existence of these harbours depends.

The changes of level in these subsiding districts may be so gradual as to be quite imperceptible to the inhabitants of the neighbourhood, whilst at other times the depression will occur suddenly, and be accompanied by earthquakes. The information which reaches us respecting the physical changes which occur as the effects of earthquakes, is generally of too meagre a character to enable us to form an opinion of the causes which have produced them; but Lyell, in his "Principles," has described several which have taken place in such localities. In 1811-12, disturbances occurred in the basin of the Mississippi, causing a subsidence of between 70 and 80 miles north and south, and 30 miles or more, east and west, in the neighbourhood of New Madrid, so that a considerable portion of the land became submerged, forming lakes. In 1692 an earthquake occurred at Jamaica, during which the greater portion of Port Royal, the then capital, was suddenly engulphed. At Chittagong, in 1762, sixty square miles of the coast to the south and east of the delta of the Ganges permanently subsided during an earthquake. And at Cutch, in the delta of the Indus, a sinking of the land accompanied with earthquakes occurred in 1819, causing a simultaneous depression in different places to the extent of from 10 to 18 feet; but the occurrence of the Ullah Bund renders it doubtful whether the latter should be added to the list. These sudden subsidences appear to me to have been the result of landslips; that is, that faults have been formed by the breaking away and falling downwards of large wedge-shaped masses of rock, separated from along the margins of the gaping fissures, which have been produced by the tension caused by the general depression of such districts, and that therefore the depth of these bays will have been by these means increased to a greater extent than they would have been simply by the subsidence alone.

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* *Geological Magazine*, 1865, page 46.

If the crust of the earth formed a rigid surface, so that neither elevation nor depression could take place, then, instead of deltas, which represent comparatively a minute portion of the enormous amount of rock which is known to have been removed from what constitutes the valley systems of large rivers, there would be enormous plains, extending for hundreds, or rather for thousands of miles, when the areas exposed to denudation are so great as 432,000 square miles, in the case of the Ganges and Brahmapootra, or 982,000 in that of the Mississippi and Missouri. But an examination of charts shows that in either case there is deep water at but a short distance from the mouths of the delta branches. In the Mississippi the 100 fathom line is marked at the distance of about 20 miles, quickly deepening to 200 fathoms, until at half the distance between it and the Straits of Florida, it is 1710 fathoms, with a bottom of clay.

Considering that the denudation of continents has been the result of subaërial and river action, which has been continuous, and that deltas and bays are the result of depression caused by the weight of the deposit of sediment pressing down the crust of the earth, it will likewise be necessary to attribute the extension of the bays towards the ocean to a previous existence of the same causes, and that their river systems were formerly greatly extended, receiving as tributaries rivers which now empty themselves into the bays, and others flowing over land now submerged to a great depth, and which is moreover covered with thick deposits, forming the beds upon which rest the waters of these extensive gulfs. There appears no other way by which to account for the re-deposit of such vast masses of material which are known to have been removed from the sides of valleys, and therefore there must be now in progress in different parts of the globe formations which will at least rival any of which there is record in Britain as having occurred in Palæozoic times. The combined waters of the Ganges and Brahmapootra, instead of emptying themselves into the sea at the site of the present delta, will at one time have extended southward to 10°, or perhaps even to 5° north latitude, receiving tributaries from the eastern slopes of Hindostan, whilst the immense amount of *débris* which has resulted from the erosion of the Himalayan Mountains and Hindostan, and been carried down by these rivers, now forms vast thicknesses of sedimentary rocks, lying at great depths in the Bay of Bengal. A similar effect will have occurred also in the case of the Mississippi, which in all probability formerly extended as far as the longitude of Porto Rico, the West Indian Islands forming the upper ridges of a range of mountains which were once the boundaries of an extension of its valley and of that of the Rio Grande. But let us compare greater things with less, and nearer home. By the same reasoning, the rivers now emptying themselves into the Bay of Liverpool — the Lune, Ribble, Mersey, Dee, Clwyd, and others—will, prior to the Glacial epoch, have all converged and formed one large river, emptying itself into what is now the Irish Sea; at all events, they will have done so as Glaciers at the commencement of the Boulder-clay period, until such time as, in consequence of depression of the land, not only the present area, but likewise a large portion of Lancashire and of North Wales, gradually became included for a period within the boundaries of the bay.

If the opinion which has been shewn to have been accepted of late years by a large number of geologists, and especially by the majority of the staff of the Geological Survey, to whom the study of the conformation of the earth is the business of their lives, is correct—viz., that valleys have been formed and that inland areas and mountain chains have been sculptured by what is known as subaërial agencies—there appears to be no other way than that which has been advanced by which to account for the redistribution of the materials which have been removed; and moreover, this is the legitimate conclusion at which we shall arrive when we consider what is known respecting river action and the formation of deltas. The phenomena of the accumulation of material and of subsidence of the land are not unfrequently alluded to by Sir Charles Lyell and others as occurring simultaneously; but with the exception of Sir John Herschel and Dr. Dawson, as previously alluded to, and of them also in reference to the present subject, I am not aware that any have considered that the one is dependent upon the other. If our great chief does not venture to associate the two as cause and effect, it is hardly to be expected that, without due consideration, you will follow me across this Rubicon, who hold amongst you, and that by your favour, the authority of a Centurion's command only. But I can demand of you, that you examine and determine for yourselves whether I have led you to the Key of the position, for I consider that denudation and deposition are the *Alpha* and the *Omega* of Physical Geology.

NOVEMBER 14TH, 1871.

THE PRESIDENT, CHARLES RICKETTS, M.D., F.G.S.,
in the Chair.

George J. F. Hewerdine, Rev. Ralph Wardlow Thompson, M.A., and Rev. Colin Brewster were elected Ordinary Members of the Society.

The following communication was read:—

THE GEOLOGY AND PHYSICS OF THE POST-GLACIAL PERIOD, AS SHEWN IN THE DEPOSITS AND ORGANIC REMAINS IN LANCASHIRE AND CHESHIRE.

By T. Mellard Reade, C.E., F.G.S., A.I.C.E.

SUB-DIVISIONS.

1.—Introduction.
2.—Physiographical Areas and Configuration of the Ground.
3.—Hydrographical Area.
4.—Base upon which the Post-glacial Deposits of the Lower Area rest.
5.—Denudation of the Boulder-clay.
6.—Washed-drift Sand.
7.—Inferior Peat-and-forest-bed, or Subterrene Land Surface.
8.—Formby and Leasowe Marine Beds.
9.—Superior Peat-and-forest-bed.
10.—Denudation of the Post-glacial Beds.
11.—Freshwater Lakes.
12.—Recent Deposits.
13.—Blown Sand.
14.—General Deductions.
15.—Summary of Conclusions.

Introduction.

The extensive and interesting group of Post-glacial deposits lying between the Rivers Mersey, Dee, and Ribble, and within their estuaries, has hitherto received very little attention. From the difficulty of collecting accurate information in relation to most of the beds, this is not surprising; and a traveller might traverse the country between the Mersey and the Douglas without even suspecting their existence, so buried are they in blown sand. With the exception of Mr. Charles de Rance, I am not aware that any geological writer has more than touched upon the subject. In Cheshire the denudation of the coast line exposes a series of beds that have been diligently investigated, from time to time, by many observers; but as their operations had been confined to a single locality, it was impossible for any very comprehensive view to prevail with regard to the origin of the beds, and their geological position.

It will be my object in the present paper to shew that in this neighbourhood we have an unsuspected mine of buried treasures in Post-glacial geology, and that from the extent of the deposits, their characteristic development and preservation, much light is thrown upon the physical conditions of the period extending from the laying down of the Lancashire Boulder-clay to the present time. To this period I propose to restrict the term Post-glacial.

Though it is usual with our best geologists, and noticeably with Sir Charles Lyell, to explain everything in the older formations of the globe by the light of causes which still continue to operate, it appears to me that few realise the truth that the destruction and reconstruction of the earth is going on as of old, and that in this, as in every known thing, *finality* has not yet been reached. The changes which take place in the short space of a life-time, though appreciable when brought to the test of exact measurement, are mostly passed over without notice, and only those which cannot escape observation are recorded as exceptional facts, instead of links in the chain of causation.

If by the publication of this paper, with the important addition of a system of maps and sections (carefully prepared from the best information at hand, and accurately laid down to scale), I can assist to dissipate these very natural notions of geological finality, I shall consider the labour not thrown away. From my position as a civil engineer I have had, perhaps, better opportunities of prosecuting the study of Post-glacial geology than falls to the lot of most, and, as will be seen from a study of the plan and sections, I have adopted, as aids to analysis, many of the methods common to engineering, but not yet used in geology. Thus, the reduction of all the sections to a common datum has much facilitated the determination of the different strata, otherwise a matter of considerable difficulty.

My attention was first drawn to the subject of Post-glacial geology by the discovery of marine shells in the excavations of the Birkdale Main Outlet Sewer, and an attempt to discover under what conditions these beds were laid down, led me very rapidly into the consideration of the subject as a whole. Having received from our Treasurer, Mr. Frank Archer, an invitation to lay the result of my investigations before the society, I do so with the more pleasure, as, though the questions I shall deal with are of general interest, in your case they have the additional one of being also local.

PHYSIOGRAPHICAL AREAS AND CONFIGURATION OF THE GROUND.

Lower Area.—The country lying between the estuaries of the Dee, the Mersey, and the Ribble, and shewn on the general plan (plate 1), as well as the whole of the Mersey under tidal influence as high up as Warrington Bridge, may be divided into two physiographical areas, the lower of which lies below the 25 feet contour. From Seaforth to Crossens in Lancashire, and forming part of this lower area, stretches what I call the Formby Plain, a continuation of which runs up into the site of old Martin Mere, and joins the plain of the Douglas Valley through a narrow neck at Rufford. The coast line from Seaforth to the mouth of the Douglas measures 24 miles. The Formby Plain is about 4 miles wide from high water mark to its eastern boundary inland, and runs up the valley of the River Alt about 8 miles. The Douglas Plain extends inland about the same distance. These Lancashire Plains (shewn blue on the plan), are mostly covered with peat, which again is overlaid near the coast with blown sand (shewn by yellow dots) or tidal silt (colored green), which follows and levels up the slight depressions in the surface forming the recent Valleys of the Alt, the Douglas, and the New Pool. With the exception of a portion of what I have called the Washed-Drift Sand, and the upper part of the present sand dunes fringing the coast, the whole of the Post-glacial deposits I am about to describe lie within, and form, the lower physiographical area, or that below the 25 feet contour. Below high water mark the shore averages over a mile wide, and many square miles of sand are, as shewn on the plan, exposed at low water.

Inland of high water mark, and below the 25 feet contour in Lancashire, the area of Post-glacial deposits is about 75 square miles.

In Cheshire equivalent deposits form the plain of the Birket, having a coast-line of about 6 miles also fringed with sand-dunes, and measure inland of high water mark about 7½ square miles.

In addition to the Formby and Birket Plains there are equivalent formations, or tidal flats, fringing the Mersey as high up as Warrington, with similar deposits in the estuaries of the Dee and Ribble.

Upper Area.—The whole of the country shewn on the map, lying above the 25 feet contour line, with hardly an exception, is covered with a greater or less thickness of Glacial-drift or Boulder-clay. Speaking generally, we may say that the more noticeable features of the landscape are due to the Pre-glacial form of the Triassic strata beneath. On what may be called the headlands, as at Ince Blundell, and Hill House, Altcar, and other prominent points, the coating of drift is but thin, while in other places, in the Pre-glacial valleys, the Boulder-clay attains a very considerable thickness. The highest point, west of a meridian drawn through Melling, is Cleve Hill (198 feet above Ordnance datum), to which locality the ground between Aintree and Scarisbrick gradually rises from the margin of the Post-glacial plains. From Walton to Edge Hill, and southwards, the ground is also elevated, and descends rather quickly to the margin of the River Mersey. On this upper area are numerous peat-mosses, the largest of which are those at Rainford, Bickerstaffe, and Kirby, which lie upon elevated plateaux, forming the watershed of the greater part of the district and stretching to the foot of the range of hills by Upholland. The drainage is, westward and northward, into the Rivers Alt and Douglas and their tributaries, and southwestward, by St. Helens, into the Mersey below Warrington; but there are minor streams, such as the Rimrose Brook at Seaforth, and the New Pool at Crossens, which are independent of these main lines of drainage, and are of considerable geological interest. The total length of the River Alt is 13½ miles, and that of the Douglas 20 miles. The White Moss plateau is enclosed by the 200 feet contour, and that at Bickerstaffe by the 150 feet contour. There are peat-mosses on the Boulder-clay lying between the Douglas and Martin Mere.

The whole upper area may be looked upon as a Boulder-clay plain, undulating over the Pre-glacial surface, with a general slope seawards, modified by the intersecting river and brook basins, which are in all cases wide and shallow.

In Cheshire but little of this upper area shews on the plan, but the same general description applies. Wallasey and Liscard occupy tolerably elevated ground, and are insulated from the main land by the Post-glacial deposits of the old Wallasey Pool. At New Brighton, in the red and yellow noses, we see the only approach to sea cliffs in the map area, though higher up the Mersey, at the Dingle and Eastham, are river cliffs. Escarpments of Boulder-clay are to be seen between Seacombe and New Brighton, along the shore for several miles above Eastham, and from Aigburth to Hale Head. The most elevated point, in the portion of Cheshire shewn in the map, is that occupied by the Observatory at Bidston.

HYDROGRAPHICAL AREA.

The low water line and the sandbanks shewn on the plan have been corrected from the latest charts, and as the banks are continually and rapidly changing, a considerable difference will be seen on comparison with the 1-in. scale Ordnance survey from which the outlines of the plan were originally taken. At several points I have given the depth of the water in fathoms, from the datum fixed by Mr. Graham H. Hills, R.N., the Marine Surveyor of the Port of Liverpool, which assumes low water of spring tides to be 10 feet below the old dock sill, or 14.25 below Ordnance datum—*i.e.*, the mean half-tide level at Liverpool. As the general sections shew the form and depths of the sea bottom, it will be unnecessary for me to describe it, excepting to remark that nowhere is the Glacial or Pre-glacial bottom, as the case may be, free from recent deposits, excepting only in the channels of the Mersey, and parts of the Crosby Channel northward to the Crosby Lightship; this freedom from deposits in the two channels being due to the great tidal scouring force of the waters of the Mersey. Elsewhere the sea bottom is composed of an argillaceous mud or siliceous silt, the banks and the bar being pure sand containing shell fragments.

BASE UPON WHICH THE POST-GLACIAL DEPOSITS OF THE LOWER AREA REST.

A careful comparison of the borings and sinkings I have been able from various sources to obtain, shews that the group of Post-glacial deposits of the area (colored blue on the map) rest upon a Post-glacial beach cut in the Boulder-clay, and that the valleys of the Alt, the Douglas, and the Rimrose and Birket brooks, pass under the deposits seawards, to a considerable depth below low water, the whole being filled and levelled up with marine formations, peat and forest-beds and old land surfaces. Borings taken for me on the shore at Waterloo, by Mr. Hall, the Surveyor to the Local Board, shew the Boulder-clay at from six to nine feet below the surface; while at Seaforth, opposite Mr. Fernie's house, it is sufficiently near to be used, after baring the sand, for garden purposes. From Seaforth northwards to Southport, the thickness of the Post-glacial deposits gradually increases, and the depth at the shore line bears a pretty constant proportion to the recession inland of the 25-feet contour line. At low water, opposite Blundellsands Road, an old wreck shewed the Boulder-clay covered by only 6 feet of sand. At Martin's Farm, at Hightown (section 18, plate 4), it was reached at 33 feet below the surface. At the Altcar pumping engines, in excavating for the foundations of the windmill (section 6, plate 4), the blue silt was not bottomed at 25 feet deep; and still further northwards, at the Palace Hotel, Birkdale, in boring for a water supply, the Boulder-clay was reached at 79 ft. 6 in. After passing through 45 feet of it, the remainder of the boring was in the Keuper Marls; but as no water-bearing strata was tapped, the boring was finally abandoned at 558 feet. From this point to Crossens the surface of the Boulder-clay rises, and, as is shewn by section a—b, plate 4, is cut through by the "Back Drain" by Crossens Mill. The village of Crossens stands upon a knoll of Boulder-clay, rising through the Formby and Leasowe Marine Beds; but as the knoll is covered by tidal silt (colored green), it does not shew on the plan. At this point, also, is the ancient Crossens river-bed (shewn in red), to be afterwards alluded to. A knoll of Boulder-clay rises through the Post-glacial deposits at Brown Edge, and at Clay Brow, a knoll of Keuper Marls, capped with Boulder-clay, as pointed out by Mr. de Rance.* At the Southport Gas Works, at Blowick (sections 1, plate 4), a boring 40 feet deep did not pass through the Post-glacial deposits; and at a point about three-quarters of a mile northwards of Bescar Lane Station, a boring shewed 21 feet of Peat, resting on White Sand.

A consideration of these particulars, together with the plan and sections, will shew that, were it possible to contour the surface of the Boulder-clay underlying the deposits, such contour-lines would be approximately concentric with those of the Boulder-clay westward of the Formby plain, and at higher levels. Again, at Rufford (15 on plate 1), piles were driven through the deposits of the Douglas valley 70 feet, without reaching the Boulder-clay. At Seaforth (9 on plate 1), in the valley of the Rimrose, a well fifty feet deep did not bottom the silts; and Wallasey Pool, in Cheshire, as shewn by the excavations for the Birkenhead Docks, occupied also a wide and deep valley in the Boulder-clay. These submarine, subterrene, and post Boulder-clay valleys, are as sure an indication of the former and Post-glacial elevation of the land, as are the submarine forests on the coast, though the period they indicate is not the same. The River Douglas has cut out Boulder-clay cliffs on its left bank at Hesketh; and as its bed at the same point and up as far as Lock House is on the Boulder-clay, the inference is irresistible that when the land was elevated the course of the river differed to some extent from its present one—probably trending more to the eastward—as otherwise, if there is not a valley of drainage elsewhere, there would have been a deep lake at Rufford, the formation of which, as far as we know, would be physically impossible. The same reasoning holds good for the River Alt and Rimrose brook, with other and minor streams now silted up.

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* Explanation of Geological map. 90 S E.

DENUDATION OF THE BOULDER-CLAY.

Evidences of a very considerable submergence of the land are tolerably abundant in districts adjacent to the one under consideration, marine shells having been found in stratified beds of sand and gravel up to 400 feet high on the Ribble, 1200 feet at Macclesfield, and over 1300 feet on Moel Tryfaen, in Wales; on the opposite side of the Irish Sea on the Three Rock Mountain at Kingston, 1200 feet high, and also, I believe, in elevated positions in the Isle of Man. These shells consist wholly of recent species, but some are of a northern character, indicating colder conditions of climate than at present prevail. Unfortunately, their exact position in relation to the Boulder-clay of Lancashire has not been yet determined. Authorities differ, and the subject demands more attention and scientific exactness than have yet been devoted to it by geologists. As I have just pointed out, the contours of the Boulder-clay underlying the Post-glacial deposits have evidently been largely formed by marine action ; and above the 25 feet contour the extensive plains of Boulder-clay already mentioned can only be planes of marine denudation. The surface-lines of the Boulder-clay in the two physiographical areas are continuous without abrupt change, and I can therefore only assume that previously to the laying down of the Post-glacial deposits the surface of the land, in both areas, was subject to the same influences; though its form in the lower one may have been modified by erosion at the time the sea stood at the 25 feet contour, as will be afterwards explained. As shewn by the preservation of the fragments of the Inferior peat-bed, it is quite certain that the main estuary of the Mersey was excavated in the Boulder-clay before any of the Post-glacial deposits I am treating of were laid down, and I believe this will also hold good of the Ribble and the Dee. These estuaries have undoubtedly since been widened in places by marine action, and originally rounded and gently sloping banks have been converted into clay cliffs. Looking at the surface form of the land as a whole, the conclusion that it has been fashioned and planed down under water forces itself irresistibly upon us.* On the other hand, the vertical cutting down of the valleys has been doubtless due to subaërial agencies when the land was considerably elevated above its present level. A glance at the valley in which Martin Mere is situated, at the Douglas valley, and the valley of the Mersey above, and the estuary below Warrington, will shew that subaërial influences alone could not have moulded them — that they could only have been fashioned by a horizontal force acting against vertical slopes or banks. In this way, and in this way only, could have been formed the flask-necked valley of the Douglas and the physically remarkable estuary of the Mersey, one mile wide at Liverpool and four miles wide above Eastham, contracting to a narrow channel again as the rock appears at Runcorn, and again widening out in a sinuous course, up to, and above Warrington. That these main forms were impressed on the estuary of the Mersey before any of the Post-glacial deposits were laid down, is clearly shewn by the deposits and peat-and-forest-beds on Helsby and Ince marshes, the deposits on Widnes marsh and the Bewsey valley (section 22, plate 4), now filled up for several miles with Post-glacial deposits and forest-beds. Mr. Binney observes of the valleys of the Irwell, Irk, and Medlock at Manchester, that "All these three valleys bear evidence of having been formed under the sea, for the action of the present streams of water which now flow in them appears to be unequal to produce the effects observed in any moderate period of time."* This is a subject demanding more consideration, and I purpose returning to it at a future time; but I think it may safely be concluded that there have been two fashioning agencies, the one vertical and subaërial, the other marine and horizontal, and if this position be admitted, it follows, that between the laying down of the Boulder-clay and the laying down of the Formby Silts, there have been not less than two elevations above the present level, and one depression considerably below it. The order would then be this:—1. The laying down of the Boulder-clay (Glacial.) 2. Its elevation above the present level, during which period subaërial valleys were formed. 3. Its depression considerably below the present level, at which time the valleys were widened, the contours rounded off, and the plains of marine denudation formed. 4. The re-elevation above the present level—the period of the inferior or subterrene peat-and-forest-bed. Many people, even geologists, are often averse to admit the frequency of these movements of elevation and depression; but independently of the coincidence I have adduced, there is an inherent probability in it, as there are the most unmistakeable signs of two Post-glacial periods of elevation in the peat-and-forest-beds I am about to describe; and when we consider the entirely recent character of these deposits as contrasted with the Boulder-clay on which they rest, we cannot help admitting, that between the laying down of the Boulder-clay and the growth of the first peat-bed an enormous length of time, unrepresented in this locality, elapsed. Frequent changes of level are the absolute conditions upon which the permanence of the earth depends, and the geological record has only to be examined to see that it is full of them. I have developed this part of the subject to shew the value of a system of minute examination over a large area, and a reference to the older works on geology—Smith's "Newer Pliocene," for instance—will shew that such intermediate movements were not then thought of. A raised beach was a sign of elevation, a submarine forest one of depression, and the one was assumed to follow the other; though later investigation shews there may be intermediate periods, meaning a very great lapse of time.

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* See Chambers' "Ancient Sea Margins," p. 223—227.

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* "Drift Deposits of Manchester and its Neighbourhood," p. 28.

Whether this view be accepted or not, it is quite certain that the Boulder-clay has been subjected to great marine as well as subaërial denudation.

WASHED-DRIFT SAND.

Lying upon the eroded surface of the Boulder-clay, and pretty generally distributed in the form of more or less extensive patches, is a sand that from the general, or rather total absence of organic remains in it other than vegetable, has caused observers much difficulty. It is the Upper Drift-Sand of Mr. Morton, and is described by him in the "Geology of the Country around Liverpool." More lately, Mr. de Rance, F.G.S., has described a sand* which is well developed at Shirdley Hill and named by him Shirdley Hill Sand. These sands, I have satisfied myself, are identical and belong to one formation, and, as a pretty extensive series of observations have shewn it distributed in disconnected patches over a much larger area than described by these writers, I have ventured to propose for it the more generic descriptive name of Washed-Drift Sand. That this sand is due to the previously described denudation and destruction of the Boulder-clay, from which it has been eliminated, I think will be conceded. That it is separated from the true drift is shewn by its unconformability to the Boulder-clay, upon which it lies, and which an examination of the sections will reveal. Again, as a rule, it rests upon thin beds of reconstructed gravel, which under Rainford Moss,† I am told, is hardened together with oxide of iron. It is remarkably free from pebbles, except in a few cases where it is more thickly developed, where bands of gravel occur at the base, as is shewn in section q—r, plate 4. Where the sand comes in contact with the peat it is white and crystalline; its normal colour is a clear yellow approaching orange, shading off to a duller hue in the lower portions, and where it is in contact with soil surfaces it develops into a dark chocolate colour and concretes together. The decomposing peat probably deoxidises the ferric oxide coating the granules, and the percolation of rainwater with carbonic acid in solution washes the residual ferrous oxide away. The water draining from this sand, as well as from the blown sand, is often of an ocherous nature, and deposits a flocculent precipitate of iron, probably the result of the loss, on exposure to the air, of the carbonic acid which held the ferrous oxide in solution and the simultaneous conversion of the ferrous into the ferric oxide. Vegetation and rainwater appear invariably to have the effect of developing iron in the sand when in contact with soil, and forming what farmers call "fox beds" or "red ore;" but it is only a superficial coating of the granules that may be chemically discharged; hence the varying hues of the sand.

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* Explanation of Geological Map 90· S.E., and Post-glacial Deposits of Western Lancashire and Cheshire—Quarterly Journal of the Geological Society, February, 1871, p. 662.

† Under this name I include the White Moss and Holland Moss, and all the moss land between Rainford Junction and Blaguegate Station.

The Washed-Drift Sand underlying the peat of Rainford and Bickerstaffe Mosses, is the highest extensive deposit within the area of the map. The preservation of the sand on the higher level plains, irrespective of the peat covering, is only what one would expect, considering the way in which subaërial denudation acts; and as after its deposition it has been subjected to great subaërial degradation and disturbance, every flood even now delivering its quota down the brooks, rivers, and rivulets, the upper beds are probably mostly subaërial, and in some cases in the valleys the whole of them. Thus we see the continuity of the geological record preserved, and sometimes in a very puzzling manner. Where, however, the sand rests upon gravel beds without intervening soil surfaces, we may be sure it occupies its normal position, and this, as a general rule, it does. In some cases floods have brought down sand from the higher levels and spread it over the brook valleys, as at Kirby, by the new church, where it covers a soil bed resting on gravel, and containing remains of vegetation. Between Bull Bridge and Alder's Bridge, on the banks of the Alt, may be seen an irregular bed of gravel not far below the surface of the sand; and this is due, doubtless, to floods. Above Bull Bridge there is an extensive deposit of sand in the valley of the Alt. At a point between Clock House Bridge and Alder's Bridge it was proved to be from 12 to 15 feet deep, resting on a gravel bed. On Aintree Racecourse it was not bottomed at 15 feet. It is well developed along the 25 feet contour from Shirdley Hill to between Hill House, Altcar, and Downholland Cross; and in all cases where the base is visible, or where I was able to try it by sinking, rests on thin gravel beds lying on the Boulder-clay. A well sunk through the moss, at 21 on map, by Shirdley Hill, shewed 12 feet of sand resting on a bed of gravel. It underlies part of the moss at Martin Mere, rising up through it on the Back Drain in a pretty extensive patch covered with furze, and generally is found under the moss of the lower area, along the inland margin, rising through it in places as at Barton, and at Newton's farm, Great Crosby, where in sinking 8 feet deep I found in the sand a few remains of hazel branches in a very rotten condition. At Bootle, near the station, the foundations of a house disclosed it underlying the blown sand, and containing an intercalated peat-bed with a soil bed between it and the blown sand. At Buckley Hill it is also pretty extensively developed, and contains intercalated peat-beds; but I could get no reliable information of its being bottomed. I have traced it along the banks of the Mersey from Garston to Hale, and in places are what appears to be the remains of a soil bed between it and the clay, shewing, if this be the case, that it is here locally subaërial. The cuttings for the new Manchester and Liverpool Extension for the Sheffield and Lincolnshire Company shew the same sand, here also resting upon an almost totally denuded soil surface, in the valley of the Mersey above Warrington.

Perhaps the most complete section is that disclosed by the excavations for the Crosby Hall Sewer (q—r, plate 4). This section did not shew the base, but nearer the Hall the sand was proved to rest on a gravel bed on the Boulder-clay. The Washed-Drift Sand here evidently fills up a valley in the Boulder-clay. At Boundary Cottage, a well 12 feet deep did not bottom the sand, though in the brook close by, the Boulder-clay is about 2 feet 6 inches from the surface. At the Home Farm, Little Crosby, it is 7 feet deep, resting on a thin gravel bed. The sand has evidently been everywhere much denuded, but not sufficiently so for the farmers, who prefer the Boulder-clay to such a hungry subsoil.

INFERIOR PEAT-AND-FOREST-BED, OR SUBTERRENE LAND SURFACE.

Evidences of a land surface posterior to the Washed-Drift Sand, and anterior to the great mass of Post-glacial deposits occupying the lower area, are preserved in places. This lower peat-bed, as it occurs on the Cheshire shore, is described by Mr. Morton, F.G.S., Mr. Chas. Potter, Mr. Jos. Boult, and many other writers,† but has hitherto not been, that I am aware of, distinctly separated from the upper peat-bed as marking a separate era of elevation of the land. Mr. de Rance, in his "explanation" before referred to, speaks of a lower peat-bed *underlying* the Shirdley Hill Sand and lying on the Boulder-clay. This I have failed to discover, the only soil or peat-beds I know of in this position being evidently covered up, as before described, by after subaërial disturbance and re-distribution of the sand. He does not, however, in his more detailed paper before referred to, published in the *Quarterly Journal of the Geological Society*, correlate the lower peat in Cheshire with that he describes in Lancashire. To the lower, or, as I have termed it, from the contained trees and other forestal remains, the *Inferior peat-and-forest-bed*, the same reasoning applies which determines the Upper or Superior peat-and-forest-bed to mark an era of former elevation of the land. That these two periods are distinct, is clearly shewn by their separation by a bed of laminated blue clay and silt containing marine shells. The two peat-beds are well shewn by the denudation of the Post-glacial deposits of the lower area on the Cheshire coast, but are rapidly being destroyed. What appears to be a similar series of deposits has been described by Mr. H. F. Hall, F.G.S., as occurring at Colwyn, in North Wales;* and I believe a patient search would shew them, more or less developed, in protected points, over a large part of the British coast; but I reserve this as a question for future consideration. The Palace Hotel boring, already referred to, showed at a depth of 78 feet, 1 foot 6 inches of mixed peat and blue clay lying on the Boulder-clay, doubtless due to the destruction and denudation of the Inferior peat-bed. The intercalated soil bed, with tree stumps erect therein, by Crosby Hall (section q—r, plate 4), I consider to be of the same age, as it underlies a continuation of the recent peat. The peat and soil beds intercalated in the Washed-Drift Sand in other places it would be difficult to determine the age of, and fragments of such a bed are to be found on the western side of Shirdley Hill itself. Section 17, plate 4,† at the Liverpool Custom House, shews the Inferior peat-bed resting on the rock 40 feet below high water mark, and separated from the Superior peat-bed by ten feet of blue silt, in which were found stags' horns. The section at the North Docks (16, plate 4), from the same source shews a peat-bed resting on the rock 35 feet below high water mark.* This is probably also the Inferior bed, and the upper one may have been destroyed by denudation. The section of the Bewsey valley at Warrington, kindly supplied to me by Mr. Jas. Muir, who had charge of the work (No. 22, plate 4), shews a peat-bed five feet thick resting upon several feet of sand and gravel. This I also correlate with the Inferior bed, and the underlying sand with the Washed-Drift Sand, out of which, Mr. Muir informs me, a few whelk shells were taken. The section shews the height to which a 21-foot tide at Liverpool would rise at Warrington Bridge; a neap tide would not reach above Fiddler's ferry, 2¾ miles below the Bewsey section. In the overlying blue clay I found *Triceratium Favus*, a marine diatom. Now, as the Superior peat-bed occurs overlying the blue clay on Helsby and Ince Marshes, at about the level of high water, it is inconceivable that the channel of the Bewsey valley should under the same physical conditions have been free from silt, a necessary supposition if the Bewsey peat belonged to the Upper series. This reasoning does not apply to the Superior peat-bed of Wallasey Pool, which dips towards the bed of the Mersey to below low water mark, as at the same period the pool must, as we shall see, have been subjected to a strong through tidal current, unfavourable to the deposition of silt. This Bewsey section has been described by Mr. Paterson,* but the overlying beds differ in Mr. Muir's section (plate 4, sec. 22) from his. Many hazel nuts were found in the peat and sand, and the skull of a bear *(Ursus Spelæus)*, now in the Warrington Museum, was taken out of the peat.

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† In Mr. Morton's Presidential Address, Liverpool Geological Society, 1869–70, will be found a complete list of all the writers on the Post-glacial Geology of the neighbourhood, and kindred subjects, that it would be well for those interested to consult.

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* "Submerged Forest at Rhos, near Colwyn."—Transactions of Liverpool Geological Society, Vol. I, January, 1866, p. 34.

† From Morton's "Geology of the Country Around Liverpool," p. 46.

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* The exact site is not given, but from the date of the excavation I judge it to be the Wellington Dock, through which, Mr. J. Ellacott, C.E., informs me the old Beacon Gutter ran, out of the peat of which hazel nuts and stags' horns were taken.

The mere separation of peat-beds by bands of marine silt is not evidence that the peats belong to different eras of elevation. It is only when they contain embedded trees and roots, and are separated by marine deposits, that we can infer, independently of collateral evidence, that they mark different eras of elevation, as we have the strongest proof peat can be formed, containing bands of, or separated by marine silt, during the periods in which subsidence is taking place. The Inferior peat-and-forest-bed having been subjected over its whole surface to great denudation, is only found in favoured and protected localities, and is never disclosed except by escarpments caused by recent denudation or by artificial sinkings.† No doubt excavations in protected spots, creeks, and valleys, would disclose much more of it than I have described.

FORMBY AND LEASOWE MARINE BEDS.

Lying upon the denuded surface of the Inferior peat-bed, or where its destruction has been complete, upon either the Washed-Drift Sand or thin beds of re-assorted gravel resting on the Boulder-clay, or in some cases upon the bare Triassic rocks, is a most important group of Post-glacial deposits.

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* "Geology of the Bewsey Valley," a paper read before the Literary and Philosophical Society of Warrington.

† The peat-beds are getting so rapidly destroyed that there will soon be few traces left, on the Cheshire shore, of the Inferior peat, for it thins out landwards. Having been subjected to denudation during two periods of depression, it is wonderful that any of it is left in this exposed spot.

It was, as I have explained in the introduction, the discovery of marine shells in these beds, in the Birkdale outlet sewer excavation, that first excited my curiosity. Mr. Frank Archer, who visited these and other excavations in the neighbourhood with me, thought the subject worthy of a descriptive paper. At this time I expressed to him my conviction that the surface of the laminated clay, or silt, represented a slightly raised beach dipping towards the east, or the opposite direction to the present shore, as shewn in section d—c, plate 4; and that the silts were laid down in the quiet waters of an embayment, formed by a sand-bank to the westward, which cut it off from the full force of the north-west winds. This opinion, so far as it went, has since proved to be correct; but not being satisfied with so local and partial an examination, I determined to trace the deposits, if there were any, over a large area, and to discover their Cheshire and other equivalents.

To look at the external features of the country—one dead flat, with an horizon on the west side of sand-dunes only, and on the east low and distant rising ground, with few remarkable features by which to distinguish the localities, save the Gothic tower of Scarisbrick Hall, the Water tower at Aughton, or the Halsall parish church—the geological prospect was far from promising. That "I was mapping out the geology of the country," was a statement received by most with a smile of incredulity; and even now that my work is completed, I have some difficulty in getting people to believe that there is any geology at all to map out. Such is a fair statement of the problem as at first presented to me.

The only place where the Lancashire deposits are naturally exposed is at the submarine forest at the Alt mouth, and to this spot I first turned my attention. A diligent and oft repeated search of the clay escarpments underlying the peat, failed to shew any organisms by which the character of the laminated clay, at that point, could be determined; though the microscope afterwards clearly revealed its nature. At the point S., on its left bank, where the Alt of late years has eaten deeply into the deposits, on digging at low water with Mr. Edwin Foster we came upon a bed of shells, principally cockles and tellinas, which I felt sure underlay the true deposit. To settle this matter by a crucial test, I had a large hole dug through the peat-and-forest-bed at 23 on map, and was gratified to find my surmise correct, by getting on to the same bed, at a depth of 5 ft. 6 in. below the surface. (See section 8, plate 4, and section on line G—H, plate 3.) The distance between the Birkdale excavations and this sinking, is over 8 miles as the crow flies. The question then arose—are these deposits, so similar in nature, continuous? A reference to the map will shew that the deposits on the coast are obscured by blown sand, but after enquiry I found that this submarine peat-and-forest-bed had been proved to be continuous by the excavations for the culvert of Far Moss Pool, and by another culvert passing under the railway by Hightown Station, and delivering the drainage of Flea Moss and part of Little Crosby, into the River Alt, just below the flood-gates. An examination of the numerous sluices, ramifying through the great peat plain, shewed the laminated blue clay invariably underlying the peat. The character of this clay differed to some extent in different localities. Thus, at 3 on map at Formby, a marl hole sunk through the blown sand and peat, shewed a remarkably fine soapy laminated clay, of a clear pale blue when first exposed, but which on drying became grey, as all these clays do. At 4 and 5 the clay is sufficiently stiff to make bricks of, which shrink considerably in burning, but which I am told absorb less water than most bricks made from the

Boulder-clay. The floodgates of the Alt are built of brick made from the local blue clay, and have stood well from 1831 to the present time. At Birkdale, on the other hand, attempts at brick making have proved a failure, the laminated clay there being poorer and more arenaceous. The Birkdale section shewed laminated clay at the outlet by Fine Jane's Brook, gradually passing into silty sand in Aughton Road westwards towards Mill Lane and the railway. Some of the sumph holes of the sewers on Birkdale Park Estate have disclosed a bed of black sand, or old soil, underlying the blown sand, and resting upon a sand full of water, also belonging to the same group of deposits. Between the Alt mouth and the excavation at 23 by the bend of the Alt before described, sinkings shewed pure sand underlying the peat. The section of the Crosby outlet sewer described by Mr. Joseph Boult,* also shewed under the soil surface below the blown sand, between the railway and the sea, a bed of sand, which caused much difficulty in laying the sewer. These sand beds appear to be confined to the sections approaching the shore; and, I am of opinion, indicate the former existence of a bar or bank extending from Southport to Crosby, inside which, as an embayment, the finer laminated silts were laid down, at each flux and reflux of the tide. Physical reasons point to this as a natural supposition, as the change of currents favourable to the laying down of the silts would first, considering the nature of the bottom, produce the sand bar. This laying down of the finer particles held in suspension in the sea water, is to be seen taking place now, in every embayment or creek where the waters are for a time comparatively motionless. It also takes place in slacks on the shore, and the argillaceous particles have doubtless been originally derived from the denudation of the Boulder-clay. The only stones I have ever found in these silts were a boulder of Carboniferous Limestone,* full of fossils, and a small piece of Red Sandstone, taken out of the Birkdale sewer excavations. A piece of water-worn Cannel coal was also derived from the same source. As a rule, excepting on some coast sections, the more tenacious clay immediately underlies the peat, and it gets siltier and more arenaceous the greater the vertical depth. It is very characteristically described by local excavators as "sea slutch;" the laminated blue clay being locally termed "Scotch." It is extremely probable that the Washed-Drift Sand of the inland margin underlying the peat has been largely re-arranged by the sea before these silts and clays were laid down. In the drainage of the White Otter, and similar pools, fresh-water mussels have been found, but these are mere surface deposits; and that this whole group of deposits is of marine origin there can be no doubt whatever. In a well at Martin's Farm, Hightown (section 18, plate 4), at 20 feet deep, a bed of marine shells occurred, and I have no doubt more would be found in other places, did the excavations extend deeper than they usually do. In a large part of the deposits immediately under the peat no shells are found, but the microscope generally reveals in these places Foraminifera and marine Diatomaceæ. On the Cheshire coast I made an extensive series of observations, which, with a careful perusal of the rather voluminous literature and controversies, called forth by the remarkable submarine peat-and-forest-beds exposed on the shore at

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* "Topography of Liverpool and the Neighbourhood."—Transactions of Liverpool Polytechnic Society, March, 1867.

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* This boulder was singular, as being enveloped in an outer friable laminated crust, which fell off or exfoliated with handling, and by an inner crust ¼ in. thick, full of iron pyrites, which also coated the fossils near to the exterior. It contained *Goniatites* and *Aviculopecten*. It may have been a nodular concretion, but certainly has been effected by alteration from the exterior inwards.

Dove Mark and Leasowe, has led me to the following conclusions, viz.:—That the Upper peat-bed is the equivalent of the Lancashire Upper bed, and that the bed or terrace of peat, or rather peaty soil, at the New Brighton end of the Leasowe embankment, and forming a base for the sand dunes, is the continuation of this Upper or Superior peat-bed.* Much confusion has arisen by the general impression that this is another bed of later date than the Superior peat-bed, and overlying it; but I am convinced that it is only the thinning out of the Superior peat in the same way as it occurs at Birkdale, as shewn in section d—c, plate 4. Underlying the Superior peat-and-forest-bed, and directly overlying the Inferior bed, is a laminated clay, closely corresponding with the Formby clay, containing *Scrobicularia piperata*, while at the Leasowe end, and from thence towards New Brighton the same bed develops into a series of sandy silts, containing a considerable variety of recent shells, not all found together, but separated into groups. Numerous sinkings at intervals through these Leasowe Beds disclosed *Tellina solidula*, *T. Tenuis*, *Cardium edule*, *Mytilus edulis*, *Pholas candida*, *Turritella communis*, and *Scrobicularia piperata*.† By the light of my previous knowledge of the Lancashire Beds, their Cheshire equivalents presented themselves in an extremely simple aspect; and the controversies that have unfortunately raged, excepting as regards the hypothesis of their formation, have been very much on matters of detail, general agreement as to the order of succession prevailing among the various writers. Section m—n, plate 4, is typical of the two peat-beds and enclosed marine clay, and is not a diagramatic but a carefully measured section. The Inferior peat-bed was proved, by sinking, at point a, to be 3 feet 3 inches below the eroded surface of the blue clay. It was only 6 inches thick, made up mostly of remains of the common flag, and emitted when first bared a most fœtid odour, being remarkably well preserved and looking extremely recent.* Under this we came upon a thin blue clay and gravel-bed, and a good-sized millstone grit boulder embedded in the brown Boulder-clay below. From o to p, plate 1 (excavations for a sluice for diverting the waters of the Birket and Fender), a good section was shewn of the deposits,† and I classify the sand containing shells, underlying the Inferior peat in that section, with the Formby and Leasowe Marine Beds—the difference in the nature of the deposits being due to local causes. Sections 12, 13, 14, and 15, plate 4, explain the position of the beds at these various points. In Wallasey Pool the Superior peat is overlaid with a considerable depth of recent deposits, that might easily be mistaken, by the inexperienced, for the Formby and Leasowe Beds.

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* Since writing this, sections of borings have been exhibited to the Society by Mr. Isaac Roberts, F.G.S., which prove it. There are no peat-beds under, and the Inferior beds are denuded at this locality, as might have been expected at the former outlet of Wallasey Pool.

† Mr. Charles Potter had previously found *Scrobicularia piperata* in the laminated clay between the two peat-beds at the Hoylake end of the embankment.

It would take up too much time to describe minutely equivalent beds in other places. In building the sea-wall at the extremity of the Dock Estate by the Rimrose a portion of these beds was exposed, and a fine pair of horns of the red deer was taken out of the blue clay. Mr. Robert

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* The Inferior peat thins out and disappears as it rises southward on the Boulder-clay slope. This may be seen in the escarpment nearer the embankment, east of this section, where about 2 inches of peat or peaty soil is seen directly under the laminated clay, with the Superior peat overlying it.

† Described by Mr. J. P. G. Smith.—Proceedings of the Literary and Philosophical Society, No. V., p. 169.

E. Johnston, C.E., informs me that the construction of the railway across the Helsby and Ince Marshes shewed an upper peat-bed 6 feet thick, containing tree trunks lying upon a blue clay, at no point bottomed by any of the excavations, which did not, however, exceed 12 feet. Under one excavation on the Helsby Marsh 25 feet piles had to be driven down before a suitable foundation was obtained, and near the same place an embankment used to subside about 8 feet per night, and for a month little progress was made, owing to the continued subsidence of the bank, due to the soft nature of the ground to be passed over. Similar formations occur at the mouth of the Weaver, and as before stated, the blue clay of the Bewsey Valley I also correlate with the Formby and Leasowe Beds. This clay was remarkable as the only one containing segregated particles of phosphate of iron of a brilliant blue color.* There are many other deposits, as those of Ditton Marsh and in the upper part of the Mersey above Runcorn, well worth examination. The description of the various sections of plate 4 gives the localities of some of the shells found in these deposits. At Birkdale, *Buccinum undatum*, *Natica monilifera*, *Turritella communis*, *Cardium edule*, *Tellina solidula*, and *Scrobicularia piperata* were taken out of the silt and laminated clay. To Mr. Charles Brown, of Southport, I am indebted for sections at the Gas Works, Blowick (No. 1, plate 4). Few shells were found in these excavations; but after a long search, Mr. Brown took out of the "scotch" thrown out of the excavations a fragment of a *Cardium*, also a *Helix*, and a *Succinea*. Mr. Robert Kitton, of Norwich, who has kindly examined some of the silts for me, has determined the whole of the *Diatomaceæ* on the slides sent as marine forms. They are—*Triceratium Favus*, *T. striolatum*, *Coscinodiscus*

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* See my paper in *Geological Magazine*, March, 1872, p. 115.

radiatus, Melosira Borrerii, Podosira maculata, Tryblionella gracilis, Nitschia Brebissonii, Navicula Jennerii, N. minutula, N. didyma, N. Westii and *Pleurosigma Balticum.* Several forms of Foraminifera were also found, and to the Rev. W. H. Dallinger, who has also examined the silts for me, I am indebted for the identification of the following—*Nonionina Scapha, N. Faba, Rotalina Mammilla, Discorbina Vesicularis, Planorbulina Vulgaris,* and *Polystomella umbilicatula; Polystomella* and *Discorbina* being the most frequent, but none of them even of average size. As, however, the silts are full of calcareous fragments, the larger ones may have been broken. Minute calcareous spheres and ovoid bodies also occur, which Mr. Dallinger suggests may be Carter's *Melobesia Unicellularis*—a calcareous alga identical with Huxley's coccoliths and coccospheres. When treated with an acid all the silts, excepting those from a few inches immediately under the peat, effervesce more or less violently. They also require a great deal of washing before the objects are distinguishable.

The horns of the red deer are frequently taken out of these beds at various places in Lancashire and Cheshire, and at Birkdale was found the metacarpal bone of a small variety of *Equus.* Skulls of the *Bos taurus* and *Bos longifrons* have been found on the Cheshire coast, together with some few other mammalian remains. No remains of the bear, that I am aware of, have ever come to light.

Human Remains.—The only authenticated case of human remains having been found in the Formby and Leasowe Beds, is the skeleton which the denudation of the Cheshire coast brought to light near Leasowe Castle. Some have contended that the silt in which it was found is more recent than the Superior peat-bed; but this is an error. I have already shewn that the thin bed of peat forming a sort of platform upon which the sand dunes at

Leasowe rest belongs to the Superior peat-bed, and under this the skeleton certainly originally lay.*

Level of the Sea with respect to the Land when the Formby and Leasowe Marine Beds were laid down.—The whole of these deposits follow with remarkable regularity the 25 feet contour line, from the mouth of the Douglas to the Mersey at Warrington, and from the Dee to the Mersey in Cheshire. At u, in Cheshire, I discovered a bed of *Scrobicularia piperata* immediately under the peat, the root fibres actually filling some of the shells. They were evidently in the place where they had lived and died, both valves being complete with the syphonal end uppermost. As the level was fully that of high water of an ordinary spring tide, the land must then have been, in relation to the sea, lower than now; and from this and physical reasons I place high water of spring tides at this period at or about the 25 feet contour line. The Birkdale deposits also point towards this fact; but while my first impression, that the surface of blue clay and silts there, represented a raised beach, was correct, I did not then realise that the whole of the deposits have at one time been considerably more elevated, but have since subsided to the level at which they are now found.

SUPERIOR PEAT-AND-FOREST-BED.

Subsequently to the formation of the Formby and Leasowe Marine Beds, the land became gradually elevated. A large portion of these silts and clays, now below high water mark, were exposed for a considerable length of time to subaërial influences, which partially moulded and modified the surface. The sea on retiring would leave the land in long undulations, for the most part following the lines of the old valleys, though the watersheds to some extent would be modified. When the water is low, in the Back Drain at Crossens, may be seen what was formerly a river-bed, but is now silted up. The level of its bottom has been proved to be not less than 10 feet below Ordnance datum, but it may be more. This is considerably below either the Alt, or the outlets of the Crossens Sluices, at the same relative points. Probably this river drained a large area of the deposits when the land was elevated. Strange to say, it must have cut through the Boulder-clay in preference to the newer deposits, but what determined its direction we can only surmise. (See section a—b and A, plate 4.) This is not a solitary phenomenon of the sort, as the Birket in a part of its course has left the newer formations, and cut its way through the Boulder-clay. The old maps of Lancashire shew Martin Mere draining into the Douglas, and if artificial means were not taken, that river would now flood the meadows occupying its site. That Martin Mere was formed within the watershed of the ancient Crossens River is more than probable, so that the arterial drainage has only reinstated the old drainage lines. On the last subsidence of the land this river bed became silted up, and Martin Mere was formed, as shewn on the old maps, with its outlet into the Douglas.

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* A description of this skeleton, by Mr. G. Busk, F.R.S., is given in the proceedings of Ethnological Society, February 7th, 1865. The skeleton is now in the Royal College of Surgeons.

The Superior peat-and-forest-bed lies upon the Formby and Leasowe Beds, and contains at its base, at numerous places, remains of an ancient forest or forests. At the Alt mouth the roots exposed by denudation may be seen striking deeply into the blue clay below. Sometimes the roots only are seen, the upper portions having entirely rotted away. The oak, pine, hazel and birch are the trees most frequently met with. Sir Edward Cust informs me a few specimens of the yew have been occasionally taken out of the moss at Leasowe, and, as may be seen in some of the fittings of Leasowe Castle, portions of the wood are occasionally sufficiently sound for joiners' and cabinet work. At Lunt many trunks of trees were found, but no roots. The trees are not by any means universally found at the base of the peat. They have evidently grown, as they do now, only in favored localities, and more frequently on the margin of the moss than in the centre. On the Hill House Farm, Great Altcar, the moss has been dug into, in places, 12 feet deep without bottoming it, and is almost wholly composed of branches and leaves of trees, sometimes beautifully preserved. The dotted line from Birkdale to Formby shews the western boundary of the moss, as far as it has been *proved.* It is from 6 to 7 feet deep along this line, and is overlaid with from 5 to 6 feet of blown sand. There is little doubt that it or equivalent soil beds extend under the whole of the sand dunes. It has been impossible to distinguish the Superior peat-bed in the general plan, but a reference to the general sections will explain its position and extent. With few exceptions, it covers the whole of the surface colored blue, and *underlies* the blown sand and also the tidal alluvium colored green. There is no doubt that the greater part of the peat is of much more recent date than the forest whose remains it has assisted to preserve. In places the lowest bed of peat is composed of remains of the common flag, which are also imbedded in the upper stratum of the blue clay, shewing that some silt has been deposited since they grew. This is probably a fresh-water deposit, but its thickness is only measured by inches. Where there are no trees at the base, small pieces of peat are often embedded in the upper 6 inches of clay. It is customary, for convenience, to classify the whole of the peat with the forest-bed; but here again in places the upper growth must be quite recent, and the beds are only another instance of geological continuity.

The thicknesss of the peat-bed in Lancashire varies from 2 feet 6 inches to over 12 feet, and in one place near Martin Mere it was found to be 20 feet thick. At Seaforth Station it is 40 feet thick, filling up the old valley of the Rimrose (section 9, plate 4). Excavations for the bridges of the Lancashire and Yorkshire Branch Railway (sections 10 and 11, plate 4), shew 12 feet of peat. This, I expect, was towards the edge of the valley. A submarine forest was formerly exposed on the shore by the Rimrose, but is now all destroyed. Sections w—x, e—f, g—h, k—l, i—j, Plate 4, shew the sections exposed by the Waterloo Sewerage Works, for the construction of which I am indebted to the assistance of Mr. W. H. Richardson, C.E., and the present local Surveyor of Waterloo, Mr. Hall. The peat belongs to the Superior bed, and mostly rests upon Washed-drift Sand. The peat in section g—h is split in two with a bed of watery sand, and section 2 at Birkdale shews it split in two with marine silt, containing shells of Scrobicularia and Tellina. The Superior Peat-bed in Wallasey Pool and the Birket valley is nearly all overlaid with recent silt, often of considerable thickness. At [15] it is 12 feet thick, but varies, as in Lancashire. The most remarkable feature in the Cheshire bed is, that it dips from this point to 12 in the River Mersey to 19 feet below Ordnance datum. Equivalent beds occupy the Helsby and Ince marshes, the valley of the Weaver, and other tidal flats between Runcorn and Warrington.

DENUDATION OF THE POST-GLACIAL BEDS.

After the growth of the forest just alluded to, the land gradually subsided to its present level. During this time and the ensuing pause, the Superior Peat-bed and Formby and Leasowe beds suffered much denudation. From the Alt mouth to the north docks nearly the whole of the peat has been destroyed by the denudation of the shore, excepting a portion below low-water mark, at 5 on section k to l, plate 3, and the sand, as a rule, rests on the bare Boulder-clay. The excavations for the Huskisson Branch Dock exhibited the same phenomena, and it is only in creeks and gulleys where the beds have been preserved. The Cheshire coast also exhibits signs of great denudation, and the coast line has undoubtedly been considerably cut back. The beds there exposed are the only remnants of an extensive area invaded by the sea, for the blue silts (Formby and Leasowe beds) have evidently been laid down in the quiet waters of an embayment, however that embayment may have been formed. Changes of the coast line are now continually taking place. It is not at all improbable that the beds have been denuded along the whole coast from the Ribble to the Mersey; but from the Alt mouth to Crossens the signs of such denudation are not to be seen, as from a change of currents the coast is now growing westwards, and the eroded edges, if they existed, of the previous beds would be covered up and obscured by recent deposits.

FRESH WATER LAKES.

Formerly, and before any drainage works were carried out, there is no doubt much of the Upper peat moss presented the appearance of a series of lakes or *meres*. The drainage of Martin Mere brought to light several canoes hollowed out of single trees.[*] In January, 1869, another was discovered,[†] and at the present time one may be seen buried in the moss at Ainsdale, at the side of a sluice not far from the mill. These are undoubted evidences of the former existence of shallow meres, but the area of the country draining into them has not been sufficient to create any great amount of fresh water deposits.

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[*] Leigh's "Natural History of Lancashire," p. 33.

[†] See Mr. Eckroyd Smith's "Archæology of the Mersey District." Transactions of the Historic Society of Lancashire and Cheshire. April, 1870.

RECENT DEPOSITS.

Tidal Alluvium.—What is denuded in one place must get laid down in another; we therefore find in all the depressions in the Superior Peat-bed, below high-water mark, to which the tide has or formerly had access, recent deposits of a character somewhat analogous to the Formby and Leasowe beds, but more arenaceous and not so homogenous in their nature. The whole Douglas valley is levelled up with them; they are found by the Old Pool at Crossens, by the Alt, and covering most of the Cheshire beds. I am also inclined to think that extensive recent deposits formerly lay upon the Superior Peat-bed in Cheshire, now exposed on the shore. The denudation of the coast has, however, destroyed most of the traces of them, but still they are found to a limited extent at the base of the sandhills. As shewing how difficult it is to predicate the actual age of any deposit, or part of a deposit, it is well known that beds have been formed in the Mersey estuary within this century which have since been nearly destroyed by denudation caused by a change of currents.* Recent deposits occur on the margin of the Mersey as high up as Warrington, and are found in most creeks and rivulets draining into the Mersey basin. The section of Garston Creek, 24, Plate 4, shews that even these minor features were excavated long before the last subsidence of the land, and are the clearest proofs of its former elevation. The river shore, and

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* Report and Memoir of the Survey of the River Mersey, 1860–61, by Messrs. Parks and Hills.

Boulder cliffs have undoubtedly since been cut back, and the bed of the creek also seems to have worked itself laterally to the S.W. The marsh clay of the Bewsey valley is a recent deposit; but as detailed descriptions are given of each section, I must for convenience, instead of repeating, refer those interested to them. The recent silts in that part of Wallasey Pool now occupied by the Birkenhead docks attained a considerable thickness, as shewn in section y to z.* Recent deposits may also be seen at the mouth of Brombro' Pool, in Cheshire, and are now being fretted away by a change in the tidal current. Wherever the previous deposits were submerged in the last subsidence, they are, in all protected localities, covered with recent silt. As shewn by the old embankments, the sea had at one time access a considerable distance up the River Alt; and previously to this, and before the first embankments were made (of the date of which I can find no record) most of the Alt recent deposits were laid down, as the old banks are made of them. Doubtless a great deal of silt was laid down within the old banks after their construction, and before the new embankments forming the present sides of the stream were made.

The Alt deposits are in most places very distinctly divided into an upper brown arenaceous or marsh clay, and a lower sludgy silt; in some places, however, finely laminated blue and yellow clay rests on the peat. There are also patches of sand. I have not observed elsewhere in Lancashire, nor in Cheshire, so distinctive a division of the recent silts. In cutting the Engine Sluice, stags' horns were found in the marsh clay, but not in the lower silt. A fine pair of horns of the red deer, and a portion of a human skull, were taken out of the recent clay at Crossens

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* The Peat-bed is nearer the centre of the Pool than the line of this section.

Mill.* Remains of the *Bos longifrons*, *Cervus elaphus*, a human skull covered with barnacles, and bones of a Cetacean were found in the excavations in Wallasey Pool,† and the vertebra of a whale in excavations for the North Docks, Liverpool. The whole of the silts are undoubtedly marine, as Foraminifera, marine Diatomaceæ, and marine shells are found almost universally in them. The silt filling up the river-bed at Crossens contains in addition Spatangus spines, and to the level of the Boulder-clay appears to be the equivalent of the lower recent silts, while that above differs in its character, and is probably the equivalent of the upper or marsh clay. The Birket silts are pretty much of the same nature, though possessing more variable beds.

Where we see a distinctive division of a deposit like that of the Alt, it is certainly the record of physical change. Change of sea currents will change the character of the deposit held temporarily in mechanical suspension in the water. We see lesser changes from day to day on the shore, and a section of the shore deposits always shews, intercalated in the sand, beds of mud, silt, and shells.

Intercalated beds of recent silt also occur in the Upper peat, splitting it in two, as seen in Section 2, plate 4, which contained great quantities of *Scrobicularia piperata* and *Tellina*. It is also seen in two of the sections at Blowick, No. 1, plate 4, and the same phenomenon was met with in borings at Downholland Moss by Messrs. Binney and Talbot.‡ Thin Peat-beds, on the other hand, are also intercalated in the upper recent silts. The phenomenon is one due to subsidence. Thus under certain conditions the tidal alluvium (shewn green) overlying the peat might get covered with a growth of peat; if the land were then to subside, the peat might get covered by more recent silt, and would present in section the appearance of two peat-beds divided at one end by silt, but uniting into one peat-bed at the other, the whole again covered by recent silt—the exact counterpart of what is frequently met with in the Coal-measures. A permanent alteration or periodical fluctuation in the vertical rise of the tide, easy to conceive, would also have the same results.

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* Since the above was written, a human skeleton was found in the recent silts in the Gloucester Road sewer excavations, Birkdale.

† These are described by Mr. T. J. Moore, F.Z.S., in the "Transactions of the Historic Society of Lancashire and Cheshire." Vol. 10. Old Series.

‡ "On the Petroleum found on Downholland Moss." Proceedings of the Manchester Geological Society, 1842–43.

Areas of Deposition and Denudation.—It may very naturally be asked, why is it that beds laid down under conditions not very dissimilar to those existing should come to be wasted away to the extent they have been in Lancashire and Cheshire? The answer is simple—*Areas of denudation and deposition are continually changing* and sometimes reversing themselves, the primary cause being changes in the direction of the tidal current. From the Crosby Lightship as a centre the main channel of the Mersey, by the closing up of one entrance and the simultaneous opening out of another, moves from west to north, forming a cycle of changes lasting nearly 100 years, which when complete commences again at the west and repeats itself. The sandbanks are also continually changing their position. All these influences, together with the winds, act and re-act upon each other, and longer cycles of change result. The lesser changes can be recorded, but the greater ones would require for their mathematical investigation more time than I have at my disposal. At present I content myself with pointing out the fact of their occurrence.

BLOWN SAND.

It would hardly be thought that denudation and deposition by the wind had caused the bulkiest of the recent deposits, but this is the case. The large area of shore exposed between high and low water is eminently favourable to the generation of subaërial sand. Between springs and neaps, when part of the shore is permanently dry, much sand gets displaced and carried inland. Thus at Formby the blown sand is three miles wide from high water mark, and the whole area of the subaërial deposits shewn on the map, is, in Lancashire about 22 square miles. The average thickness cannot be less than 12 feet, some of the sand dunes rising 75 feet above Ordnance datum. Were it not for the planting of starr grass and great attention, the sand would even now encroach on the land. Soil surfaces showing traces of cultivation are frequently seen intercalated in the sand where excavations are made, shewing a struggle with nature on the part of the agriculturist such as we may fancy takes place on the edges of the desert, in Egypt, bordering on the Nile. Occasional Peat-beds are also met with, and also beds of freshwater shells which have lived in the slacks of the sandhills. Above the Superior Peat and below the sand dunes, in Cheshire, occur several extensive freshwater beds, and on the same zone the Roman antiquities were found at Hoylake. All these beds have been so frequently described, that I should be wasting your time to do more than allude to them.

GENERAL DEDUCTIONS.

Climate.—It will be seen from the nature of the organic remains described, that no great climatal changes have taken place; but I think the inference may be fairly drawn that the hygrometrical condition of the atmosphere has varied. The climate of Lancashire is humid, and this, together with the stiff clay subsoil, is favourable to the growth of Peat-mosses, which are general, and have been more so in former times; artificial drainage, both in the high and low lands, together with cultivation, having had the same effect as a dryer atmosphere. Looking at the remains of ancient forests so generally found at the base of both the high and low level mosses, containing sometimes immense trees, oaks up to 7 feet in diameter,* one cannot resist the impression that there has been a general physical change of condition over an extensive area of the western coast.

I have shewn that forestal remains occur at 40 feet below high water mark, and Post-glacial valleys at over 70 feet, but it would be absurd to limit the elevation to this latter as a maximum, the probability being that it has been much greater.† That England and Ireland were united in the period of the Inferior, and again in the Superior Peat-beds, is not improbable; but under any circumstances, during the time the land was elevated, a much larger area would be exposed to the atmosphere, and the general influence of this would be in the direction of a dryer climate. In Ireland the destruction of the ancient forests seems to have been general and complete, and certainly in no place in Lancashire would

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[*] An oak tree of this diameter was found in the railway cutting through Rixton Moss, near Warrington. See paper before referred to, by Mr. Paterson.

[†] Dr. W. King, says:—"When dredging on the west side of the Dogger Bank, off the coast of Durham, in about 50 fathoms of water, the dredge brought up a large quantity of dead specimens, in a chalky condition, of *Mya truncata*, which, Dr. King considers, lived on the spot when the Dogger Bank was a "subaërial surface."—*The Geologist*, vol. vi, p. 169.

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Persistence of Valley Lines.—One of the most remarkable facts which has come under my observation is the persistence with which denudation seems to follow the Pre-Glacial valley lines. Minor alterations of course occur, but I should say on the whole that the watersheds are now very much what they were before the Glacial deposits were laid down. It follows from this, that those great legendary alterations in the courses of rivers which have such a hold on the popular imagination, never occurred.* That Wallasey Pool has never been an estuary of the Mersey since the period of the Formby and Leasowe Marine Beds, is certain. At that period it doubtless was an estuary, but not the main one, and the division of the tidal current by what at high water would then be the Island of Wallasey must have had an influence upon the deposition of the Formby and Leasowe Beds. The current through Wallasey Pool at that time would prevent the deposition of the silt in it, thus accounting for the great dip of the Superior Peat-bed towards the Mersey.

Area of the Vertical Movements.—It would be presumptious, without further investigation, to pretend to define the limit or boundary of these vertical land movements; but I believe they have been over a very large area, as shewn by the submerged forests to be found not only in most protected places around the British Isles, but also on the coast of France. The correlation of these deposits with those I have described would be a work of time; but I trust I may be able at a future time to take some steps towards a solution of the problem.

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* Mr. Robert Bostock has neatly exposed some of these delusions in his communication to the Society of March 8th, 1870.

Historical Evidences being upon Geological Time.—The Roman remains, coins, fibulæ, &c., particularly described by Dr. Hume in "Ancient Meols," and since from year to year by Mr. Eckroyd Smith, were mostly found on the surface of the Superior Peat-bed on the shore near Hoylake. It is quite evident, however, that these have been washed out of an overlying soil at the base of the sand-hills by the encroachment of the sea. Dr. Hume says:—"As many as 5,000 objects connected with the past have been found on this coast below high water mark, illustrating different ages and uses, and of nearly twenty different sorts of material." * At first it was naturally supposed that these antiquities were contained in the peat itself; but Mr. Eckroyd Smith now places them in the overlying bed of silt, while Mr. Charles Potter, who has devoted much time to the shore and has latterly collected many antiquities, says, describing this soil surface:—"With these broken marine shells I have found three species of *Helix*, the latter being generally in better condition than the former. Mixed with these I have discovered Roman and Mediæval remains. Although I have carefully sought, I have never found a fragment of man's handiwork embedded in any of the *lower* strata."† Before reading this I had, from local inquiries, arrived at the conclusion that the Roman antiquities were confined to the soil surface, which, I may observe, retains traces of former cultivation.

Having abundantly shewn that the silts overlying the Superior Peat are of tidal origin, and laid down since the last vertical land movement took place, it follows that this movement of depression was pre-Roman.‡ Now it is quite certain that such a number of objects could not have been left in this locality had there not been a considerable Roman occupation, and this also points to the fact of the land having then extended seawards a considerable distance. I am fully convinced that all the changes that have taken place, since the Roman occupation, have arisen from the *horizontal* encroachment of the sea and the erosion of the Post-glacial land surfaces.* It is quite possible that there may have been sand-dunes on the then land northwards, even during Roman times, which have since encroached landwards, burying and preserving these interesting relics of the past.

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* Supplement to "Ancient Meols," page 52.

† See "Observations on the Cheshire Coast."—Transactions of Liverpool Geological Society, 1868-9. p. 42.

‡ From independent considerations, very clearly expressed, Mr. Robert Bostock, in the paper before referred to, arrives at the same conclusion.

When we consider the smallness of the geologic changes that have taken place during the last nineteen centuries, compared with those represented by the two eras of elevation, and again by the valleys of denudation marking the lapse of time between the first of these eras and the true Glacial period, and the deposits of which we have here only an imperfect representative, we may form some notion—though still an inadequate one—of the enormous length of time separating us from those days when Glaciers flowed down the Snowdon valleys, and icebergs, laden with the spoils of more northern regions, deposited their burdens in the then icy seas of Britain.

SUMMARY OF CONCLUSIONS.

A careful consideration of the facts already stated has enabled me to come to the following conclusions:—

1st.—That since the laying down of the Boulder-clay the land has been elevated above its present level, and has been again depressed considerably below it, the main portion of the present Lancashire and Cheshire river valleys having been excavated during this period and the subsequent re-emergence of the land. The *Washed-Drift Sand* was eliminated from, sorted, and reformed out of the Boulder-drift, and scattered over the country, but has been much denuded and displaced since by atmospheric and aqueous influences above the 25 feet contour, and by subaërial and submarine denudation below that line.

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* Much confusion has arisen from most of the writers on these antiquities having failed to distinguish clearly between effects due to *subsidence* and those due to *horizontal erosion*.

2nd.—On re-emergence, the land was again elevated above its present level, and a pause favourable to growth occurred, during which time the "*Inferior Peat-and-forest-beds*," or subterrene land surfaces were formed. The vertical extent of this and after movements will be considered at a future time.

3rd.—A second period of subsidence followed, and a pause occurred at or about the 25 feet contour line; considerable denudation of the *Inferior Peat* took place, and afterwards the *Formby and Leasowe Marine Beds* were laid down.

4th.—The latest vertical upward movement succeeded the formation of the *Formby and Leasowe Marine Beds*, and upon them, as a land surface, now grew the forest trees, remains of which are seen at the base of the *Superior Peat-bed.* They are traceable from the mouth of the Douglas, by Formby and Waterloo, to the little creek at Garston, and even up to the Bewsey valley at Warrington, and on the opposite Cheshire shore from the Mersey to the Dee, and as far up the Mersey as the Ince and Helsby marshes and the mouth of the River Weaver. The river bed at Crossens was excavated during this period of elevation.

5th.—The last movement of the land now took place, and was downwards. The river bed at Crossens was silted up, and the drainage of Martin Mere reversed into the

Douglas. The drainage generally was obstructed, and here and there beds of tidal silt were intercalated in the growing peat. The tidal silt overlying the Superior Peat-bed by the Douglas, the Alt, and the Birket, the silt which overlay the Peat-bed of old Wallasey Pool, and that in which the vertebra of a whale now in Brown's Museum was discovered at the north docks, and all the deposits to which I confine the term *recent* belong to this period, in a pause of which we are now living. These silts are again in places being denuded or "*fretted*" away; and though there is and has been since the Roman occupation a cessation of vertical movement in the land, horizontal displacements by erosion, and re-formation by deposition, are still taking place, due solely to changes of tidal and river currents—agencies capable of effecting much greater change than is usually supposed, and the effects of which, even within the limits of the last century, I hope at some future time to show, are capable of measurement and exact calculation.

DESCRIPTIONS OF PLATES.

MAP, OR GENERAL PLAN.

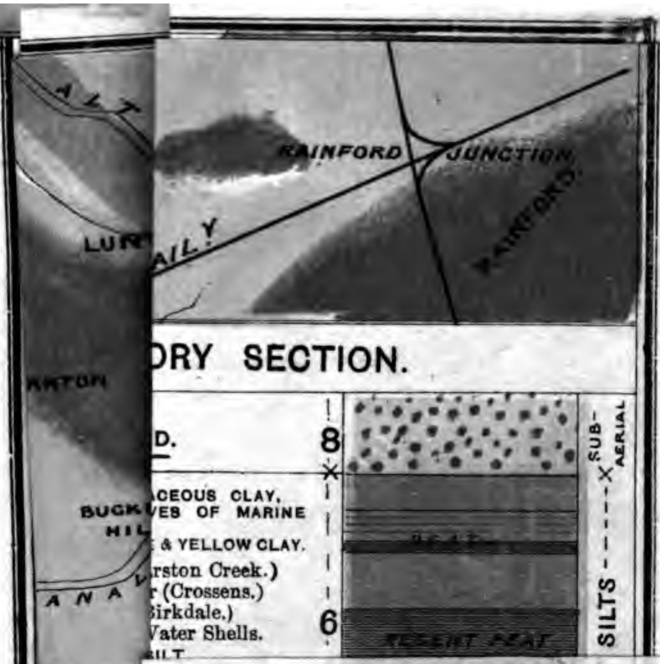
PLATE 1.

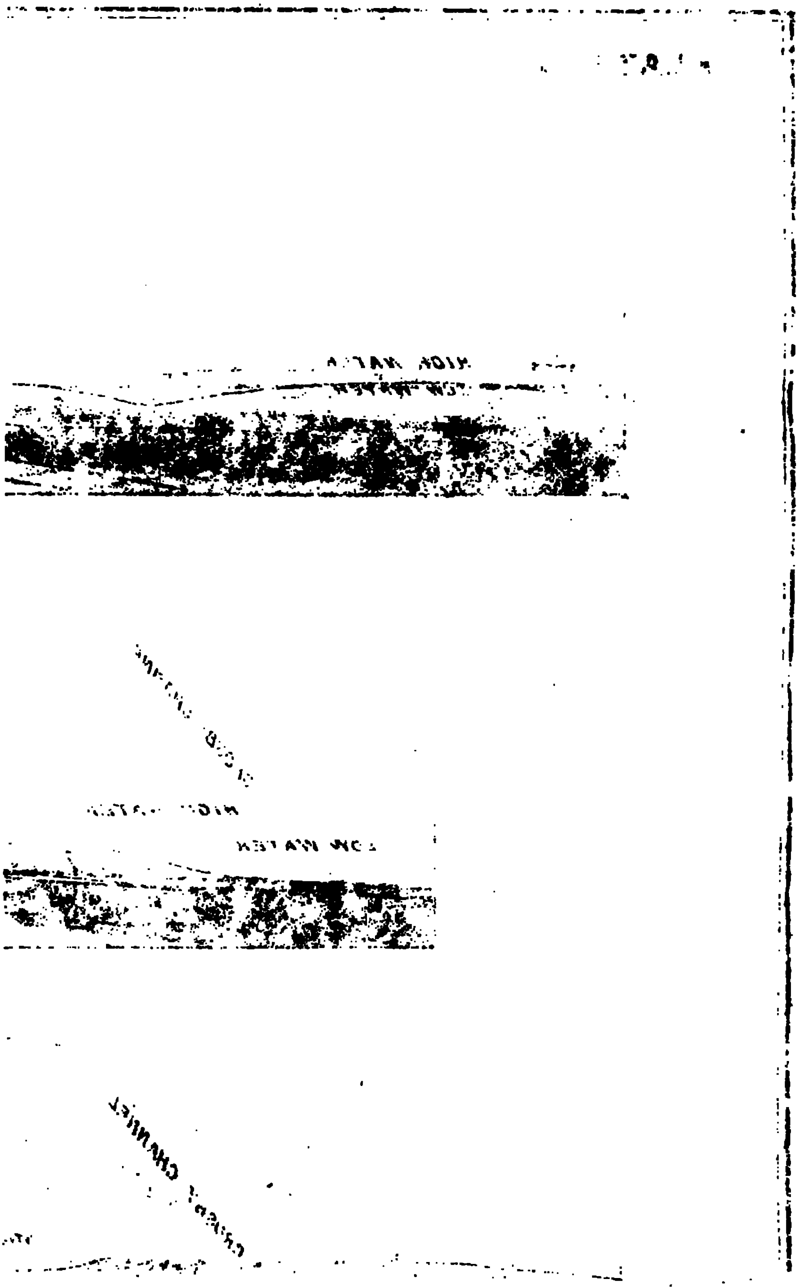
Map or General Plan of the Country lying between the Rivers Mersey, Dee, and Ribble, on a Scale of 1 inch to the mile.

Note.—The distinguishing colors of the different beds on the plan are the same as in the Explanatory Section. As the same colors represent the same beds on the whole of the four plates, the distinctive divisions will be understood at a glance.

The depths of the sea-bottom are given in *fathoms* below the datum line fixed in 1860 by the Marine Surveyor of the Port of Liverpool, viz.:— 10 feet below the Old Dock Sill, or 14·25 below Ordnance datum. This chart-datum is the level of low water of a high spring tide. The heights of the sandbanks and shoals are given in *feet* above the same datum.

The numbers refer to the detailed vertical sections on Plate 4. The lines of the General Sections on Plates 2 and 3 are terminated with capital letters; those in detail, on Plate 4, with small letters.


ALT
LUN
RAINFORD
JUNCTION
AILY
RAINFORD
RTON
BUCK
HIL
ANAL
D
DRY SECTION.
D.
CEOUS CLAY,
VES OF MARINE
& YELLOW CLAY.
rston Creek.)
r (Crossens.)
Birkdale.)
Water Shells.
SILT
8
6
PEAT
RECENT PEAT
SUB-AERIAL
SILTS



As it would be impossible, from the manner in which it is scattered about the country, to shew the *absolute* boundary of the Washed-Drift Sand, the edge of the deep yellow colour representing it, is shaded off. In places the sand is, as already described, not less than 15 feet thick, in others only a few inches, while in some places the Boulder-clay may be quite bare, even in the yellow area. The deep yellow colouring must in fact be taken to shew the localities only in which the Washed-Drift Sand is most abundantly found. The Map is only *geologically* coloured landwards from high water mark. The light yellow colour in the Hydrographical Area represents only the sand banks and shore which are dry at low water.

GENERAL SECTIONS.

PLATES 2 AND 3.

These are drawn to a horizontal scale of 2 inches to the mile, or double the scale of the Plan, and to a vertical scale of 192 feet to the inch. They are therefore vertically exaggerated about 14 times.

As will be seen, the whole of the sections, Plates 2, 3, and 4, have been reduced to Ordnance datum (shewn by a red line), or 4.25 feet above the Old Dock Sill. By levelling from the Ordnance bench marks to the Old Dock Sill bench marks, the difference of level of the two datums proves to be as stated—4.25 feet—which data I have adopted. In the "Abstract of Levelling in England and Wales," Memoirs of the Ordnance Survey, the difference between the Ordnance assumed plane of reference and the zero of the self-registering tide gauge, which is, or is intended to be, at level of the Old Dock Sill, is stated at 4.67. The *true* mean water, as shewn by the self-registering tide gauge, is 0.068 *below* the Ordnance datum or assumed plane of reference for the levelling in England and Wales. In geology, of course, such minute differences may be practically discarded. It was necessary, however, for me to explain why the difference of level is taken at 4.25 instead of 4.67.

The various beds lying upon the Triassic strata are numbered, as well as colored, to correspond with the Explanatory Section, and are as follows:—

No. 1.—Boulder-clay (purple.)
„ 2.—Washed-Drift Sand (deep yellow.)
„ 3.—Subterrene Land Surface remains [Inferior Peat-and-forest-bed] (black.)
„ 4.—Formby and Leasowe Marine Beds (blue.)
„ 5.—Superior Peat-and-forest-bed (black.)
„ 6.—Tidal Alluvium overlying the last bed (green.)
„ 7.—Recent Silts and Sandbanks (grey to light yellow.)
„ 8.—Blown Sand—Sand-dunes (dotted brown, on light yellow ground.)

It is unnecessary to describe each section, as a reference to the sectional lines on Plan, Plate 1, and Detail Sections, Plate 4, will enable them to be understood without comment.

The positions of the 25, 50, 100, 150, 200 feet contour-lines are marked on the sections with these numbers, and the whole of the sections, and those on Plate 4, are, as already described, reduced to the Ordnance datum, shewn by a red line. The vertical extent of the tidal oscillations above and below this datum is shewn in blue lines. The maximum vertical rise of the tide, at the highest springs, from high to low water, is 31 feet; but, with a strong north-west wind, it has reached 33 feet.

DETAILED SECTIONS.

PLATE 4.

The various beds are coloured to correspond with the Explanatory Section; but as these coloured groups have to be subdivided for descriptive purposes, the numbers only refer to the particular beds on each separate section.

SECTION a to b.

From opposite Crossens Bank, up shore outlet, and along the Back Drain to Water Lane.

No. 1.—Boulder-clay, very red towards N.W. end, extremely hard, fracturing irregularly, and marbled with blue veins and vertical partings in foundations of Cylinder Bridge. Some of the clay is very full of shell fragments.

„ 2.—Red shelly Sand, enclosed in the Boulder-clay.

„ 3.—Patch of Peat, 4 in. thick, lying on the Boulder-clay.

„ 4.—Sand, with Shells, ditto.

„ 5.—Peat, a few inches thick, ditto.

„ 6.—Fine Blue Silt, falling to powder when dried, containing Foraminifera, Spatangus spines, and Marine Diatomaceæ.

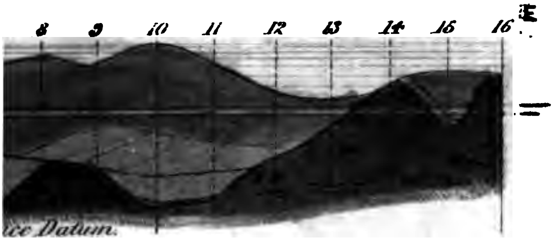
„ 7.—Tidal Alluvium, partly laminated with Sand partings. Dries hard. Contains *Triceratium Favus*. At the mill a fine pair of horns of the red deer *(Cervus elaphus)*, 2 ft. 8 in. long, and portions of a human skull were taken out of the foundations 15 years ago, at a depth of about 7 feet below the surface.

„ 8.—Recent Silt. Since the shore outlet works were executed, about 13 years ago, the fore-shore has been raised in level by deposits of Silt. Sand formerly on its surface has disappeared.

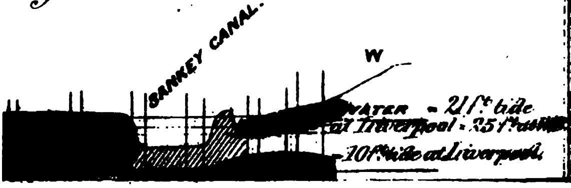
NATURAL SECTION OF RIVER BED AT A.

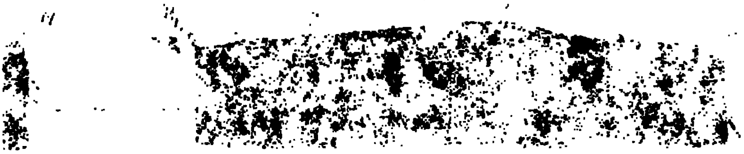
Both the horizontal and vertical scales are the same as the *vertical* scale of *all* the other sections.

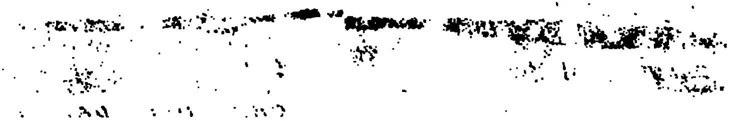
Level of Railway
duct
DITTON MARSH
the other Sections.

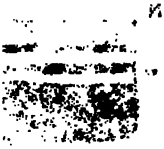

8
9
10
11
12
13
14
16
16
E
ce Datum.

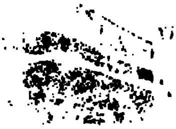
y to z.

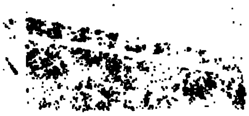

SANKEY CANAL.
W
WATER = 21 ft tide
at Liverpool = 25 ft
10 ft tide at Liverpool.











The figures 1, 6, 7 correspond with the beds already numbered and described in the previous section. The actual depth of the Silt No. 6 has not been obtained, but it has been tried with a 21-feet iron rod without bottoming it. As the depths in these sections vary, they cannot be stated, but can be obtained by scale.

SECTIONS AT 1.

Vertical sections at 1 are on the site of the new Southport Gas Works at Blowick. They are selected from 39 borings that were taken over about 5 acres of land, *all* of which sections differed in the depth, number, position, and thickness of the Peat beds.

SECTION a.

Depths given from the surface downwards:—

Blown Sand	2 feet	1 inch.	
Moss	0 „	4 „	(pasture with sand blown over.)
Blown Sand	1 „	0 „	(making water.)
Peat Moss	2 „	6 „	
Light "Scotch"	2 „	9 „	
Dark "Scotch"	3 „	9 „	
Peat Moss	1 „	6 „	
Light "Scotch"	5 „	0 „	bottom of bore hole.

Total depth.. 18 feet 11 inches.

SECTION d.

Blown Sand	8 feet	0 inches.	
Peat Moss	2 „	0 „	
"Scotch"	1 „	6 „	
Peat Moss	2 „	0 „	
Scotch	1 „	0 „	
Fine Loam, mixed with Sand	28 „	0 „	bottom of bore hole.

Total depth ..42 feet 6 inches.

It will be unnecessary to detail beds in sections b, c, and e, as the same general description applies to all. The silts were not bottomed in any of sections. The head and antlers of a red deer were taken out of the silts, but at what depth I am unaware. A bed of cockle shells was found in the tidal alluvium.

NATURAL SECTION AT 2.

Excavations in Mr. Sawyer's brickcroft near the Ash Tree Inn, Birkdale.—Horizontal and vertical scale same as vertical scale of the other sections.

This section I have had carefully levelled from the nearest Ordnance bench mark.

Surface level at W., 22.15 feet.

Blown Sand	4 feet	9 inches.	
Peat Moss	3 „	2 „	
Blue Silt	2 „	0 „	contained valves of *Scrobicularia piperata* and *Tellina.*
Peat Moss	1 „	0 „	

Surface Level at E., 20.85 feet.

Blown Sand, with bed of *Succinea* and *Valvata*....	3 „	3 „
Peat Moss	4 „	7 „
Blue Silt	0 „	9 „
Peat Moss	1 „	3 „

Laminated clay and silt under, depth unknown.

These two beds of Peat evidently unite further eastward, and are practically one bed split in two with tidal alluvium.

A trial hole was sunk at a, about 17 feet deep. Many marine shells were met with, including *Turritella;* also the second year's horn of a red deer in three fragments, but perfect when joined. The metacarpel bone of a small variety of horse was found just under the lower Peat bed. Other bones were found, but got thrown away and could not be determined.

SECTION d to c.

Birkdale Outlet Sewer from Fine Jane's Brook to west of Railway.

These levels are all accurately given to scale. E is the inland boundary of the blown sand which has encroached on former cultivation, from time to time, as shewn by intercalated soil surfaces, and has also been won back by the cultivator from time to time. The depth of the peat moss at 2 is about 7 feet; it gradually thins out eastward until at 3 it is a soil surface; after this it is in patches, and finally disappears as shewn. Great quantities of *Scrobicularia piperata* were met with between the Tanks and Elm Road. At E the "Scotch" is pretty stiff, but it becomes towards Hall Lane very sandy and sludgy, and proved very treacherous ground for the sewer. *Turritella communis, Cardium edule, Tellina solidula, Buccinum undatum* and *Natica monilifera* were also met with. The Scotch and silts here, it is pretty certain, are very deep, but were only proved the depth shewn in the Tank excavation. The tibia of a small variety of horse was found in the soil bed near Mill Lane, and in Mill Lane, in the same bed, the tooth of a boar and some small fragments of bones, all encrusted with phosphate of iron.

None of the peat hitherto described contains trunks of trees, only branches and thin stems of birch and alder, and great quantities of the common flag. (*Iris pseud-acorus.*)

SECTION 7.

Disclosed by the excavations for foundations of the Alt floodgates in 1830. Described to me by the late Christopher Houghton, Surveyor to the Alt Commissioners.

Marsh Clay, containing thin peat bed.
Peat-and-forest-bed.
Blue Clay; 3 to 4 feet.
Blue Silt. (Total depth of this group, 18 feet.)
Clay; 3 feet.
Red Quicksand; the foundations of Piers being built on timber cradles.

SECTION 18.

Well sunk at Joseph Norris' farm, by Mr. William Bromley, of Burscough, in July, 1870.

Soil	0 feet	10 inches.
Peat	2 „	0 „
Blue Clay (no Shells)	10 „	0 „
Yellow and Blue Silty Clay	7 „	0 „
A Bed of Marine Shells—(*Turritella*, &c.)		
Silt (bore hole)	13 „	0 „
Boulder-clay.		
Total depth	32 feet	10 inches.

SECTION 19.

Well at Church House, Altcar. Drawn from description by Christopher Houghton.

SECTION 6.

Foundations of the Earl of Sefton's Windmill for working the second set of pumping engines for draining Altcar.

Soil and Marsh Clay	about	5 feet	0 inches.	
Silt	„	11 „	0 „	
Peat-bed	3 to	4 „	0 „	
Silt, not bottomed at		25 „	0 „	from surface.

The cutting of the Engine Sluice in 1842 (12 feet deep at the south or engine end, and extending with diminishing depth to Altcar,) was all in recent silts, and did not reach the Peat bed. The upper bed, about 5 feet deep, was brown marsh clay. Stags' horns, shells, &c., were found in this bed, but not in the silt below.

SECTION 8.

Submarine forest at the Alt mouth. Surface level approximately reduced from high water mark.

Peat softer at top, but very hard near the base (split the spade); the lower part entirely made up of branches, twigs, leaves, &c.	2 feet 4 inches.
Alternate layers of laminated clay and silt, containing towards the bottom round balls of peat about from ¾ to 1 inch in diameter	3 ,, 2 ,,
Shell bed, mixed with blue silt, the first 6 inches being very full of shells, single valves, broken valves, and comminuted fragments, principally *Cardium edule* and *Tellina solidula*	1 ,, 6 ,,
Sandy Silt, in layers, (not bottomed)	1 ,, 6 ,,
Total depth	8 feet 6 inches.

SECTION 20.

In Blundellsands Road East. Trial hole for sewerage works (per Messrs. Dixon and Sleight.) Surface level, 36.00.

Soil and Sand	2 feet 3 inches.
Wet Sand	9 ,, 8 ,,
Running Sand and Pebbles size of beans	3 ,, 4 ,,
Wet Bog	5 ,, 6 ,,
Blue Clay	2 ,, 0 ,,
Total depth	22 feet 9 inches.

SECTION q to r.

Outlet Sewer for Crosby Hall.

Soil and Brown Sand	3 feet 4 inches.
Hard Peat	0 ,, 4 ,,
Yellow Sand	3 ,, 4 ,,
Soil, with occasional trees, about as thick as a man's thigh, rooted in	0 ,, 6 ,,
Yellow Sand	3 ,, 6 ,,
Gravel and Sand Bed	1 ,, 0 ,,
Sand (not bottomed)	3 ,, 0 ,,
Total depth	15 feet 0 inches.

At N. W. end the recent Peat of the great plain overlaps the sand, and the soil bed thins out and disappears. The beds run nearly parallel with the surface.

SECTION 9.

Well-sinking by Seaforth Station. Information from Mr. Joseph Sawyer.

Peat	30 feet	0 inches.	
Bed of clean White Sand, containing Shells	1 „	0 „	
Peat	9 „	0 „	
Blue Slutch (bored)	10 „	0 „	(not bottomed.)
Total depth	50 feet	0 inches.	

The water was so fœtid that the well was abandoned.

SECTION 10.

Excavation for Bridge at Junction on Line from North Docks to Aintree. This and No. 11 is from Mr. Arthur Holme, C.E. (Levels accurate.)

Peat	22 feet 0 inches.
Boulder-clay	—

SECTION 11.

Excavation for Crosby Road Bridge.

Blown Sand	8 feet 0 inches.
Solid Peat	18 „ 0 „
Rock	—
Total depth	26 feet 0 inches.

These are evidently not in the centre of the Rimrose Gulley.

SECTIONS w to x, e to f, g to h, k to l, i to j.

These are constructed from notes, information, and sewerage sections supplied by Mr. W. J. Richardson, C.E., and Mr. Hall, Surveyo to the Waterloo and Seaforth Local Board. (Levels accurate.)

Beds.—No. 1	Boulder-clay.
„ 2	Sharp White Sand.
„ 3	Peat Bed.
„ 4	Blown Sand.

In Section g to h, No. 3 is split in two with watery sand. At 5 the Rimrose Valley is shewn diagramatically, but its depth has not been proved excepting as shewn on Section 9.

SECTION u to v.

Supplied by Mr. W. H. Clemmey, Surveyor to the Borough of Bootle.

No. 1.—Boulder-clay.
„ 2.—Sand and Gravel.
„ 3.—Peat.
„ 4.—Blown Sand.

SECTION 24.

Disclosed in the excavations for new dock at Garston, 1871. (Levels approximate.)

No. 1.—Rock.
„ 2.—Boulder-clay.
„ 3.—Coarse flesh-coloured Sand.
„ 4.—Yellow Sand.
„ 5.—Soil, with tree rooted in it as shewn.
„ 6.—Blue Silt or Mud, with *Scrobicularia piperata*.
„ 7.—Sand of present shore.

SECTION 16.

From "Geology of the Country around Liverpool," by Mr. G. H. Morton, F.G.S., page 45.*

SECTION 17.

Ditto, page 46; extracted from the *Liverpool Courier*, 1829. Shews two Peat-and-forest-beds separated by blue silt, in which stags' horns were found. For further information I must refer the reader to Mr. Morton's book.

SECTION 12.

In Low-water Basin, Birkenhead.

NOTE.—I am indebted to Mr. J. Fosbery Lyster, the Engineer to the Dock Board, for an inspection of the records of a series of borings taken in Wallasey Pool in 1843 and 1855. The Silt and Peat are unfortunately not separated in the records. The position of the Peat is therefore given from independent information. The rock upon which the Blue Clay underlying the Peat rests is 30·25 below Ordnance datum.

SECTION 14.

Well at Mr. Williams' Nursery Gardens, Leasowe Road, Wallasey. (Levels approximate.)

Blown Sand	1 to 2 feet.
Blue Clay	8 „ 0 „
Bog	2 „ 0 „
Gravel and Boulder-clay	
Total depth	10 feet 0 inches.

SECTION 13.—By the Birket.

Silt and Blue Clay.
Peat not bottomed.

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* This section was probably on the old Beacon's Gutter in Wellington Dock. Mr. Ellicot, C.E., informs me that stags' horns and nuts were found in the peat.

SECTION 15.

From Section by Mr. J. P. G. Smith.

No. 1.—Boulder-clay.
„ 2.—Sand, with Marine Shells.
„ 3.—Peat, with trees at base.
„ 4.—Marsh Clay.

SECTION m to n.

Horizontal scale ⅛ the vertical. (Levels taken approximately from high water mark.)

1.—Boulder-clay.
2.—Peat-and-forest-bed proved at a to thin out and continue under the upper Peat bed.
3.—Laminated Blue Clay, containing *Scrobicularia piperata.*
4.—Peat-and-forest-bed.
5.—Overlying Blue Clay, denuded except in upper portions.
6.—Beds containing Roman antiquities and fresh water beds. (Described particularly by Morton, Potter, and others.)
7.—Sand-dunes.

SECTION s to t.

Submarine Forest at the Alt mouth.

1.—Laminated Blue Clay and Silt (shewn in section 8), denuded by the Alt at b.
2.—Peat-and-forest-bed.
3.—Overlying Sandy Soil.
4.—Sand-dunes.
5.—Recent Silt laid upon the denuded surface of the Laminated Clay.

The coast has been cut back at this point some 50 yards within the last 20 years, but it is growing in most other places.

SECTION 22.

Bewsey Valley, Warrington. Section supplied by Mr. Jas. Muir. Engineer to the Contractors. Surface Levels given by Mr. R. Vawser, C.E., Borough Surveyor of Warrington, to whom I am indebted for much information.

1.—Rock.
2.—Sand, resting on a bed of Gravel. (Contained a few whelk shells.)
3.—Peat-bed (contained skull and bones of bear.)
3.—Blue Clay, containing *Triceratium Favus* and segregated particles of phosphate of iron.
5.—Marsh Clay.

NOTE.—The overlying beds differ from those given by Mr. Paterson in his section, but correspond with what I myself saw at one of the piers.

SECTION y to z.

From Wallasey Bridge towards the Copper Smelting Works on the site of Old Wallasey Pool.

I am indebted to G. Fosbery Lyster, Esq., C.E., Engineer to the Mersey Docks and Harbour Board, for the information upon which this section is founded.

Figures 1 to 16 inclusive, represent a series of borings taken in 1849, by the late Mr. Rendell, C.E., along the then proposed line of the north wall of the Great Float, which was nearly coincident with the high water mark of a 15 feet 8 inch tide.*

The following are the particulars of a few of the borings:—

No. 5.—Dark Silt..............	12 feet	0 inches.	Surface level..10.75.
Strong Red Clay	24 ,,	6 ,,	
No. 6.—Light-colored Silt......	16 ,,	6 ,,	,, ,, .. 9.75.
Clean Sand............	5 ,,	3 ,,	
Strong Red Clay......	15 ,,	0 ,,	
No. 7.—Dark Silt	21 ,,	6 ,,	,, ,, ..10.50.
Wet Dark Sand........	14 ,,	6 ,,	
No. 9.—Dark-colored Sandy Silt..	12 ,,	6 ,,	,, ,, ..11.05.
Soft Blue Clay	11 ,,	0 ,,	
Rough Sand	2 ,,	0 ,,	
Stiff Red Clay..........	10 ,,	4 ,,	
No. 10.—Light-colored Silt......	22 ,,	3 ,,	,, ,, ..15.90.
Light-colored wet Loamy Sand................	10 ,,	0 ,,	
Wet, dark, sharp Loamy Sand......	6 ,,	3 ,,	
Red clean Sand	2 ,,	3 ,,	

SECTION 25.

Across the Mersey, in line with the Runcorn Viaduct.

This section is reduced from one kindly supplied to me by W. Baker, Esq., C.E., Engineer-in-Chief to the London and North Western Railway Company.

No. 1.—Pebble-beds of the Bunter Sandstone.
,, 2.—Red Clay (New Red).
,, 3.—Loam and Quicksand.
,, 4.—Marsh Clay.
,, 5.—Shifting Sand Shoals.

The absolute position of the Bunter was not proved beyond the point a. Between that and the Red Marl under Ditton Marsh there is probably a fault.

To avoid a too exaggerated appearance, this section is drawn to half the vertical scale of the other sections.

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* The tidal heights stated are in all cases from the usual datum, viz., the Old Dock Sill, or 4.25 feet below Ordnance datum.

DECEMBER 12TH, 1871.

THE PRESIDENT, CHARLES RICKETTS, M.D., F.G.S.,
in the Chair.

The following communication was read:—

REMARKS ON THE VOLCANIC ROCKS NEAR EDINBURGH.

BY THE PRESIDENT.

THE chief physical features and the picturesque scenery for which Edinburgh is remarkable, are greatly dependent upon the presence of rocks of volcanic origin, which, in consequence of their hardness, have in a great measure been preserved from erosive action, especially from that of the great ice-sheet which during the Glacial Period covered the land, and whose marks are left engraved upon the hard intrusive Greenstone of Salisbury Crag, &c., whilst the softer sandstones and shales with which they are associated have been planed away, in this manner determining the direction and depth of the intermediate valleys; thus the summit of Arthur's Seat consists of Basalt and Volcanic Conglomerate, being the remnant of the crater of a volcano which existed subsequently to the upheaval and extensive denudation of the whole of the upper beds of the Carboniferous strata; Castle Hill is surmounted by a mass of Basalt, which, Mr. A. Geikie suggests, not improbably formed the centre of eruption from which the igneous rocks of Calton Hill and Arthur's Seat were ejected during the Lower Carboniferous period; St. Leonard's and Salisbury Crags are belts of Greenstone intruded in directions nearly parallel to that of the stratification; Calton Hill is the record of a series of volcanic eruptions, repeated again in consequence of a fault at the eastern extremity of Arthur's Seat, which were ejected during the Lower Carboniferous period, being interstratified with sandstones and shales situated considerably below the Burdie house Limestone.

The whole series of bands of volcanic rock constituting Calton Hill were illustrated by specimens obtained from each bed, as described by Prof. Geikie in "Memoirs of the Geological Survey: the Geology of the Neighbourhood of Edinburgh," page 27.

In the Carboniferous Limestone formation situated north of the Frith of Forth and extending from Kinghornness to near Kirkaldy, are a succession of ash-beds and lava-flows, some of which latter are distinctly columnar, interstratified with the limestones and ripple-marked shales and sandstones which there represent this geological period; dykes of trap-rock also traverse the beds. The succession of sedimentary rock includes likewise the Millstone Grit and Coal-measures of Edinburgh and Fifeshire, which, deposited on and lying conformably to the ripple-marked surfaces of the Carboniferous Limestone formation, indicate that the locality was during the whole of this period essentially one of subsidence; the whole thickness of the Carboniferous strata of Edinburgh being estimated at 5500 feet.

There is a frequent recurrence of interstratified volcanic rocks in what at the time of their eruption were subsiding areas, not only in the Carboniferous rocks of this district and in other Palæozoic strata, as the Llandeilo and Caradoc formations of North Wales, where numerous and thick bands of volcanic ashes and lava-flows lie interstratified and therefore contemporaneous with these deposits, but they also at the present time occur frequently in marine areas in localities which likewise bear indications of being areas of depression. It was contended that their occurrence under such circumstances must be due to fissures dependent on the tension caused by the depression, which, progressing, has extended these fractures through the whole thickness of the earth's crust, and thus opened a way by which the molten rock in the interior has found a passage to the surface.

JANUARY 10TH, 1871.

THE PRESIDENT, CHARLES RICKETTS, M.D., F.G.S.,
in the Chair.

The following Lists were brought before the Society by GEORGE H. MORTON, F.G.S.:—

MINERALS THAT OCCUR IN THE NEIGHBOURHOOD OF LIVERPOOL, WITH THE LOCALITIES, &c.

1	Quartz,	Keuper Sandstone,	Oxton, Cheshire.
2	Calcite,	Coal-measures,	Huyton Quarry.
3	Dolomite,	Do.	St. Helens.
4	Gypsum,	Boulder-clay,	Egremont.
5	Baryte,	Millstone Grit,	Grimshaw Delf.
6	Salt (Psend.)	Keuper Sandstone,	St. James' Cemetery.
7	Pyrite,	Coal-measures,	Huyton.
8	Marcasite,	Do.	Huyton.
9	Hematite,	Bunter Sandstone,	Liverpool.
10	Iserine,	{ Greenstone in Boulder-clay }	Egremont.
11	Chalybite,	Coal-measures,	Huyton.
12	Wad,	Keuper Sandstone,	Toxteth, Liverpool.
13	Malachite,	Coal-measures,	Thatto Heath.
14	Galena,	Do.	Do.
15	Blende,	Do.	Do.

SHELLS FOUND IN THE GLACIAL DEPOSITS AROUND LIVERPOOL, WITH THE LOCALITIES, &c.

1 Tellina solidula, *Pult.* ‡	....	Boulder-clay, Linacre.
2 Tellina proxima, *Brown.*†	Lower Drift Sand, Birkenhead	....
3 Tellina balaustina, *Linn.**	L. D. Sand, Birkenhead	Boulder-clay, Edge Hill.
4 Mactra truncata, *Linn.* *	....	Boulder-clay, Kirkdale.
5 Lutraria (elliptica ?) ‡	....	Boulder-clay, Linacre.
6 Astarte sp. ? †	L. D. Sand, Birkenhead	....
7 Cyprina Islandica, *Linn.* ‡	L. D. Sand, Birkenhead	Boulder-clay, Linacre.
8 Cardium edule, *Linn.**	L. D. Sand, Birkenhead	Boulder-clay, Kirkdale.
Cardium echinatum ‡	....	Boulder-clay, Linacre.
9 Ostrea edulis, *Linn.*†	L. D. Sand, Birkenhead	Boulder-clay, Linacre.
10 Pecten opercularis, *Linn.*†	....	Boulder-clay, Linacre.
11 Pilidium fulvum, *Müller.**	L. D. Sand, Egremont	....
12 Dentalium entalis, *Linn.*‡	....	Boulder-clay, Linacre.
13 Littorina littorea, *Linn.*†	L. D. Sand, Birkenhead	Boulder-clay, Linacre.
14 Turritella communis, *Risso.**	L. D. Sand, Egremont	Boulder-clay, Storeton.

15 Aporrhais pes-pelicani, *Linn.*‡	.. ..	Boulder-clay, Linacre.
16 Natica sp ? †	L. D. Sand, Birkenhead	Boulder-clay, Linacre.
17 Murex erinaceus, *Linn.*†	L. D. Sand, Birkenhead	....
18 Purpura lapillus, *Linn.*†	L. D. Sand, Birkenhead	Boulder-clay, Linacre.
19 Buccinum undatum, *Linn.*†	L. D. Sand, Birkenhead	Boulder-clay, Linacre.
20 Fusus Islandicus, *Chemn.*‡	....	Boulder-clay, Linacre.
21 Trophon clathratus, *Linn.*‡	....	Boulder-clay, Linacre.
22 Nassa reticulata, *Linn.**	L. D. Sand, Birkenhead	Boulder-clay, Linacre.
23 Nassa incrassata, *Müller.*†	L. D. Sand, Birkenhead	....

* "Geology, Country around Liverpool," by G. H. Morton, F.G.S., 1863, p. 43.

† Collected by Mr. Edward J. Mathews, while sinking a well in Old Chester Road in 1844, and by Dr. Ricketts, F.G.S., at the Gas Works, in 1865, both in Birkenhead.

‡ "Section of the Boulder-clay at the Gas Works, Linacre, near Liverpool." By Isaac Roberts, F.G.S. "Abstract Proc., Liverpool Geological Society," Session 12th, 1870–1.

FEBRUARY 13TH, 1872.

THE PRESIDENT, CHARLES RICKETTS, M.D., F.G.S., in the Chair.

CHARLES BROWN and EDWIN FOSTER were elected ordinary members of the Society.

The following communication was read:—

NOTES ON THE GRAVEL PIT AT COLWYN.

By Hugh F. Hall, F.G.S.

MARCH 12th, 1872.

The President, CHARLES RICKETTS, M.D., F.G.S., in the Chair.

The following communications were read:—

ON SOME FOSSIL FERNS IN THE RAVENHEAD COLLECTION, FREE PUBLIC MUSEUM, LIVERPOOL.

By the Rev. Henry H. Higgins, M.A.

It will not be necessary for me on the present occasion to offer more than a few remarks on the general character of the Fern remains found by myself at Ravenhead, inasmuch as the identification of the species has been very carefully worked out by Mr. F. P. Marrat, to whose zeal, ability, and perseverance we are indebted for some of the most valuable portions of our local natural history.

Throughout the fossiliferous beds exposed in the railway cutting near Ravenhead, specimens of the remains of Ferns occurred; but in some of the beds much more abundantly than in others.

The immediate neighbourhood of the bridge near the south end of the cutting, where the upper and lower Ravenhead coals were exposed, afforded most of the ironstone nodules, some of which exhibited fronds and leaves of great interest; and there also, in the shales above and below the coal-seams, occurred all the specimens of delicate Hymenophylloid Ferns.

Fifty yards further to the north the cutting passes through sandstone beds rich in the remains of *Calamites*, *Halonia*, *Lepidodendron*, and *Pycnophyllum*, but yielding few Ferns. Further still, in the vicinity of the Pigeon-house coals, the sandstones contained some Ferns, most of which were found in the former locality.

The Elk's-horn Fern, *Acrostichum alcicorne*, cultivated in most greenhouses, is well known as producing at its base or rootstock certain broadly rounded leaves of large size, differing entirely from the upright fronds whence its name is derived. A similar habit seems to have characterised several of the Ferns of the coal period, the basal leaves of which have been included in the genus *Cyclopteris*. These leaves were rather numerously represented at Ravenhead.

The graceful aestivation of living Ferns lasts for so short a time that examples could hardly be expected to occur plentifully in a fossil state. The smaller and more delicate of two specimens in the Ravenhead collection was found in a spot affording many examples of Footneri.

A favourite greenhouse plant, the Hare's-foot Fern, *Davallia Canariensis*, is remarkable for its spreading root-stock covered with a soft hairy growth resembling fur. The tip of a similar rhizome is figured in pl. 1, f. 2. But a still more interesting fragment, shewn in pl. 12, f. 7, has probably been a portion of the stock of a Fern thickly beset with paleae or chaffy scales resembling those borne near the base of the stems of some of our British Ferns.

No fossil Fern was found shewing well marked remains of sori or fructification of any kind. Besides the series retained, hundreds of specimens were rejected after having been unsuccessfully examined for traces of fructification.

Stems from one to two inches in diameter occurred in the sandstone beds much eroded but exhibiting in parts markings sufficiently distinct to warrant their assignment to the tribe of Ferns. Fragments of much larger stems also occurred, with oval scars indicating the attachment of branches, which from their size must have belonged to true Arboreal Ferns. These Ferns put forth from the stem, especially towards the base, a thick crop of adventitious rootlets, which descending in close contact with the trunk often form a radicular envelopment, sometimes greatly exceeding in thickness the diameter of the true stem, which tapers downwards in the form of an inverted cone. The lower extremity of the true stem is at length elevated above the soil and the trunk with its crown of widely spreading fronds becomes wholly supported by the adventitious rootlets.

These remarks, derived from M. Schimper, threw much light upon a considerable number of specimens which I had previously regarded as very obscure. In these specimens the diameter of the adventitious rootlets is less than one-tenth of an inch. Lying close together they may roughly be compared with a bundle of knitting needles. A horizontal section shews their whitish ends bordered with black, forming a spotted pattern, which has suggested the name *Psaropteris* Schimper, from *Psar*, the Greek name for starling, the fossil bearing some resemblance to the spotted plumage of a starling.

The Fern vegetation of Ravenhead in the coal period must have been magnificent and highly varied. But a few yards of productive matrix were removed; and of the specimens disturbed, no doubt thousands unseen by any one were again buried. Nevertheless, the gleanings secured abundantly show that from the lordly Tree-Fern to the delicate Filmy-Fern, from the rigid Alethopteris to the slender trailing Fern with the habit of Lygodium, representations of all the groups had been growing nigh each other, and forming a collection that might rival the stock of a conservatory derived from all quarters of the world.

ON THE FOSSIL FERNS IN THE RAVENHEAD COLLECTION.

By F. P. Marrat.

A better opportunity could scarcely have been afforded than the one of which the Rev. H. H. Higgins availed himself in forming this collection, nor could the strata have been so successfully worked by any person residing at a distance from the cutting.

It will be seen that about sixty species of Ferns have been identified. Many of these will be found to possess a more than usual interest, on account of the localities in which they have hitherto occurred being situated in districts widely apart. The present is, perhaps, one of the most varied collections ever obtained in a single locality. The railway cutting is an extensive one, and afforded a far greater area of workable materials than is usually obtained from an ordinary shaft. One section of the Ferns, viz., those allied to the recent genera Hymenophyllum and Trichomanes deserves special notice on account of the number and variety of the plants determined, some of which have not hitherto been recorded as British species. Several of the species are identical with those found in the State of Illinois, North America. It is not among the Ferns alone that specimens of considerable interest are to be found in this collection, but nearly all the genera occurring in the Coal-measures are well represented. Several Ferns have been placed under the names of the species considered to be the nearest allied. This will account for the number of (?) placed after the names. It is only when the plants appeared remarkably different from any other species, either figured or described, that I have ventured provisionally to give new names; and as all the descriptions of such species will be accompanied by figures, it is hoped that my caution will not be found to have been inadequate. An examination of the fossil plants in the Ravenhead Collection has confirmed my preconceived views, that a considerable amount of variation is the rule and not the exception in most of the sections, if not in every branch, of Natural History. Very few plants will be found to agree precisely with the figures, or even with the descriptions given of them by the authors who have named them, and there are so many intermediate forms, that careful investigation often leads to the unsatisfactory conclusion that three or four presupposed species probably constitute various parts of one and the same plant.

ORDER I.

SPHENOPTERIDEÆ.

FAMILY I.

SPHENOPOLYPODIACEÆ, *Sch.*

SPHENOPTERIS, *Gymnogrammides.*

1. SPHENOPTERIS (Gymno.) TRIFOLIATA, *Artis.* Tab. II. In the plate accompanying the Liverpool Naturalists' Field Club for 1870-1, our plant has the pinnules much smaller and rounder than the specimen, figured by *Artis*; but I have no doubt of its being the upper part of the frond of that species.

2. SPHEN (Gymno.) CORIACEA, *Marrat*, pl. 9, f. 1–2. A magnified leaf, 2 A.

Frond bipinnate or tripinnate, pinnæ alternate, sessile, crowded below, distant above; pinnules alternate, very close, those on the lower pinnæ cut into seven rounded lobes, which are hollow in the centre, those on the upper pinnæ are trilobed and rather distantly placed; rachis very strong, grooved; the nerves are only seen in the pinnules on the upper pinnæ, the primary flexuous, the secondaries once or twice forked. This has more the appearance of a distinct species than most of the allied forms; but if we regard the plant figured as Sphen. trifoliata *Brongn.*, tab. 53, fig. 3, as belonging to Sphen. irregularis, and the Sphen. dilatata, *Lindl.* and *Hutt.*, vol. 1, tab. 47, as being a form of Sphen. trifoliata, *Artis*, there is very little evidence of a distinctive character to separate Sphen. irrregularis, *Sternb.* Sphen. coriacea, *Marrat*, Sphen. rigida, *Brongn.*, and Sphen. trifoliata, *Artis.*

3. SPHEN. (Gymno.) IRREGULARIS, *Stern.*, latifolia, *Lindl.* and *Hutt.*, vol. 2, tab. 156, and vol. 3, tab. 178.

4. SPHEN. (Gymno.) POLYPHYLLA, *Lindl.* and *Hutt.*, vol. 2, tab. 147.

SPHENOPTERIS, *Chilanthides.*

5. SPHEN. (Cheil.) HOENINGHAUSII, *Brongn.*, tab. 52. A single plant.

6. SPHEN. (Cheil.) OBLIQUA, *Marrat.* Pl. 9, f. 3. A magnified leaf, 3 A.

Frond bipinnate, pinnæ lanceolate rather broad, oblique, alternate, rachis slender, somewhat flexuous, pinnules cut into several irregular lobes, decurrent at the base, and set obliquely on the secondary rachis; primary nerve flexuous, secondaries for the most part single (rarely furcate) in each lobe.

A delicate small species, with peculiar oblique pinnæ and pinnules, resembling S. Conwayi in miniature, but with totally different nervation. 5 or 6 specimens.

7. SPHEN. (Cheil.) EXCELSA, *Lindl.* and *Hutt.*, vol. 3, tab. 212. A fragment.

8. SPHEN. (Cheil.) PLUMULA, *Marrat*, pl. 5, f. 3. A magnified leaf, 3 A.

Frond bipinnate, pinnæ lanceolate, pinnules divided into from 3 to 7 lobes; the lobes broad, irregularly crenate, the terminal lobe much the largest; primary nerve strong, the secondaries dichotomous, divergent; the rachis somewhat flexuous.

SPHENOPTERIS, *Davallioides.*

9. SPHEN. (Davall.) PALMATA, *Schimper*, tab. 28, f. 1.

A large series of specimens of this plant were collected, and among them is one of more than usual interest—pl. 4, f. 6. It exhibits the upper part, probably the terminal pinna, with the leaves small and distant, and the stem or rachis curved, showing the creeping habit of the species. Numerous specimens, most of which are in fine condition.

10. SPHEN. (Davall.) GRACILIS, *Brongn.*, in Prod. p. 51. FRAGILIS, *Brongn.* A small fragment.

SPHENOPTERIS, *Dicksonioides.*

11. SPHENOPTERIS (Dicksonioides) TRIDACTYLITES, *Brongn.*, tab. 50. Two specimens.

A figure of this plant will be found in the plate accompanying the Proceedings of the Liverpool Naturalists' Field Club for the year 1870-71, fig. 12.

SPHENOPTERIS, *Aneimioides.*

12. SPHENOPTERIS (Aneimioides) OBTUSILOBA, *Brongn.*, tab. 53, f. 2.

Several plants, the leaves of which are much smaller than the figured specimens.

13. SPHENOPTERIS (Aneimioides) LATIFOLIA, *Brongn.*, tab. 57, f. 1 to 4.

A plant almost as variable as the Neuropteris heterophylla; we have many specimens, scarcely two of which are alike.

14. S. (Aneimioides) ACUTA, *Brongn.*, tab. 57, f. 5. A very pretty specimen, figured in the plate issued with the Liverpool Naturalists' Field Club for 1870-71.

15. SPHEN. (Aneimioides) (?) PULCHRA, *Marrat*, pl. 8, f. 1. Magnified pinnules, f. 1 A 1. B. Frond bipinnate, pinnæ elongato-lanceolate, alternate, pinnules from three to five-lobed, very numerous, from 15 to 20 on each side of the secondary rachis, alternate, somewhat crowded, striated, terminal pinnule trilobed, smaller than the lateral; primary nerve flexuous, secondaries once or twice forked; rachis slender, delicately striated.

FAMILY II.

SPHENOHYMENOPHYLLEÆ.

SPHENOPTERIS, *Hymenophyllides.*

16. SPHENOPTERIS (Hymenophyllides) TRICHOMANOIDES, *Brongniart*, tab. 48, f. 3. About a dozen plants, mostly in the ironstone.

17. SPHEN. (Hymen.) MARGINATA, *Dawson*, Quart. Jour. Geol. Soc., vol. 18, tab. 15, f. 38.

18. SPHEN. (Hymen.) CURTILOBA, *Dawson.* A few fragments in ironstone, var., pl. 5, f. 5. A magnified leaf, f. 5 A.

19. S. (Hymen.) FURCATA, *Brongn.*, tab. 69, f. 4 and 5. Five or six specimens, not more perfect than those figured.

20. S. (Hymen.) SPINOSUS, *Goepp*, pl. 4, f. 1-5. 6 fragments.

21. S. (Hymen.) FOOTNERI, *Marrat*, pl. 8, f. 2-3. A magnified leaf, 3 A.

Frond bipinnate or tripinnate; pinnæ lanceolate, alternate; rachis angularly flexuous, very slender; pinnules membranaceous, the extremities of the lobes angular, deeply lobed; nerves flexuous, sunk, single in each lobe, rarely bifid. Allied to the Sphenopteris quercifolia Goepp, but will be found to be very distinct on comparison.

S. Footneri. Named after the engineer of the railway, who kindly afforded every facility for collecting these fossils.

SPHENOPTERIS, *Trichomanoides.*

22. Sphenopteris (Trichomanoides) delicatula, *Brongn.*, tab. 58, f. 4. Saarbruck. A single plant figured in the plate in the proceedings of the Liverpool Naturalists' Field Club for 1870-71.

23. Sphenopteris (Trichomanoides) dissecta, *Brongn.*, tab. 49, f. 2 and 3,—var., pl. 5, f. 1-2.

24. Sphen. (Trichom.) multifida, *Marrat*, pl. 5, f. 4. Magnified leaves, 4 a and b.

Frond repeatedly divided, pinnæ alternate, ascending, flexuous, very slender; pinnules or lobes repeatedly forked, forming a kind of miniature stag's horn; primary nerves single, with a single nerve passing into each lobe. A very delicate plumose plant, unlike anything I have seen.

Order II.

NEUROPTERIDEÆ.

CYCLOPTERIS, *Brongn.*

25. Cyc. trichomanoides, *Brongn.*, tab. 61, f. 4.
This is probably the lower leaf of a Neuropteris.

NEPHROPTERIS, *Brongn.*

Cyclopteris of most authors.

The generally received opinion regarding this genus is that most of the plants comprising it are the lower pinnules of Neuropterous species. *Lindley* and *Hutton*, under the head Neuropteris ingens, *Lindl.* and *Hutt.*, a plant now well known to be a lower leaflet of the Neuropteris auriculata, *Brongn.*, give the following statement:—"Is it not possible that Cyclopteris obliqua and Neuropteris ingens may both be leaflets of the same plant, the former coming from the base and the latter from the sides of the divisions of the leaves, like the roundish, auriculated, and oblong leaflets of Neuropteris auriculata?" Again, speaking of the characters of Neuropteris ingens, we have the following by the the same authors:—"Their texture seems to have been membraneous, if we can judge from the very filmy and delicate state of their impressions. The outline was rather wavy and the apex rounded, the base was apparently heart-shaped and more or less oblique; the veins are almost those of Cyclopteris, that is to say, they radiate from one common point with little or no tendency to run into a midrib, but in some species they decidedly do coalesce.

We have another statement by Lesquereux, in the Paleontology of Illinois, which strongly supports this view of the question. Under the head of Neuropteris rarinervis Bunb. page 429, after describing the veins as being divided into pairs in both the Neuropteris and those considered to be Cyclopteris, thus remarks:—"I have lately received from Newport, R. I., a specimen of this species with a round leaf (Cyclopteris) attached to the base of a branch bearing small lanceolate oblong leaflets (Neuropteris), a conclusive proof of the indentity of both forms. The Nephropteris denticulata, *Marrat*, shows the position of an amplexicaul leaf attached to the stem, but unfortunately there are no other portions of the plant; and the sharply denticulate edge of the leaf introduces a new feature with regard to these forms. Could this have been simply a bract differing from the pinnules on either the upper or lower rachis of the plant?"

The **Neuropteris hirsuta**, *Lesquereux,* pl. 35, f. 6-10, has Nephropteris or Cyclopteris lower leaflets, not unlike Nephropteris obliqua, *Lindl.* and *Hutt.*

The **Neuropteris ingens**, *Lindl.* and *Hutt.*, may have belonged to more than one species of Neuropteris. The individual specimens are extremely variable, *inter se.*

26. **Nep. orbicularis**, *Brongn.*, tab. 61, f. 1-2.

Probably the lower leaf of Neuropteris auriculata, var., Villiersii, *Brongn.*

27. **Nep. obliqua**, *Brongn.*, tab. 59, f. 3, *Lindl.* and *Hutt.*, tab. 90. Supposed by Geinitz to be the lower leaflets of Neu. auriculata.

28. **Nep. reniformis**, *Brongn.*, tab. 61, f. 1.

29. **Nep. oblata**, *Lindl.* and *Hutt.*, vol. 3, tab. 217.

30. **Nep. triangularis**, *Marrat,* tab. 1, f. 1.

Leaf triangular, thin, the nerves fine, raised and sharply defined, bifid, all more or less wavy, converging towards the base, dichotomous towards the margin, leaf brown, nerves very dark, nearly black.

An exceedingly distinct and well marked form.

31. **Nep.** , species (?) pl. 12, f. 1-2.

These represent two portions of the same leaf, the one being the upper and the other being the lower part.

The specimens are not quite perfect.

The specimen figured pl. 12, f. 6, appears to belong to the same plant.

32. **Nep. denticulata**, *Marrat.* Figured in the Proceedings of the Liverpool Naturalists' Field Club for 1871, pl. 1, f. 13.

Leaf amplexicaule, about 1 inch in diameter, deeply and sharply toothed, situated on a somewhat slender rachis, nerves radiating from the base of the leaf, very numerous, repeatedly forked.

NEUROPTERIS, *Brongn.*

SUBGENUS EUNEUROPTERIS, *Sch.*

33. N. CORDATA, *Brongn*, tab. 64, f. 5.

Rounded pinnules of the same. *Lindl.* and *Hutt.*, tab. 41 A, in ironstone.

34. N. FLEXUOSA, *Brongn.*, tab. 68, f. 2, and tab. 65, f. 2-3.

Var., with rounded auricular lobes at the base of the pinnules.

35. N. GIGANTIA, *Sternb.*, *Brongn.*; tab. 69. *Lindl.* and *Hutt.*, tab. 52.

36. N. LOSHII, *Brongn.*, tab. 73.

37. N. TENUIFOLIA, *Scloth*, *Brongn.*, tab. 72, f. 3.

38. NEUROPTERIS HETEROPHYLLA, *Brongn.*, tab. 71-72, f. 2.

This was a plant of large size, having foliage of the most diversified character. It is almost impossible to give anything like an adequate description of it without describing the scattered fragments, either figured by the various authors who have written upon this subject, or the specimens to be found in public and private museums. A specimen of the rachis in the Ravenhead Collection measures six-tenths of an inch in diameter, with the leaves one inch and a quarter long. If we compare these leaves with those on the specimen figured in the work of Lindley and Hutton, table 183, the primary rachis from which this large fragment of a frond was detached must have been between two and three inches in diameter. A single leaf in the ironstone is of an intermediate size—that is, twice as large as the leaflets on the former specimen, and only about one half as large as the one figured. The leaflets of Lindl. and Hutt.'s plants are broadly lanceolated, with a cordate base on the one side, and divided into about seven pairs of oval lobes on the opposite side of the rachis. A very interesting specimen in the Ravenhead Collection may be thus described: The upper pinnules lanceolate rounded at the base, pinnate, sissile; below these are three spathulate leaves, the next pinnule is elongated at the point and lobed at the base, and is supported, like the three former pinnules, on a rather long and somewhat broad leaf-stalk. On the opposite side of the rachis the pinnules are either approximately or distantly lobed. This is one of the most remarkable specimens I have seen.

Another plant has the upper pinnules simply pinnate, similar to those on the pinnæ of the last plant described, but in this specimen the leaflets are ovate in form. Below these the leaves throw off a pair of rounded detached lobes, and next to these there are from three to five distinct rounded lobes on each pinna. If to the forms already enumerated we add the fine terminal fronds figured by Brongn., tab. 71, we may be able to form some idea of the extent of variation to which this extraordinary plant was subject.

The plant figured at plate 6, f. 1 and 1 A, is the one spoken of above, and like the specimen described by *Lindl.* and *Hutt.*, resembles the Neur. acutifolia, *Brongn.*, tab. 64, f. 6-7, but the nervation is somewhat different, as will be seen by reference to the figure of the magnified leaf, fig. 1 A.

39. N. AURICULATA, *Brongn.*, tab. 66. *Artis*, tab. 7. Felicites asmundæ.

40. VILLIERSII, *Brongn.*, tab. 64, f. 1. See Nephropteris arbicularis, *Brongn.*, ingens, *Lindl.* and *Hutt.*

M. GEINITZ ALSO UNITES THE NEPHROPTERIS OBLIQUA, *Brongn.*, with these species.

41. N. HIRSUTA, *Lesqr.* Geol. Surv. of Illinois, tab. 35, f. 6-10.

42. N. THYMIFOLIA, *Sternb.* SORETII, *Lindl.* and *Hutt.* Tab. 50.

43. N. OBCORDATA, *Marrat*, tab. 2, f. 5. Simply a leaf of some unfigured species.

44. N. LINDLEYANA, *Sternb.* LOSHII, *Lindl.* and *Hutt.*, tab. 49.

45. N. EVENII, *Lesquer.* Geol. Surv. of Illinois, tab. 36. Allied to N. Grangeri and Cistii, *Br.*

46. N. SORETII, *Brongn.*, tab. 70, f. 2.

ODONTOPTERIS, *Brongn.*

47. O. LINGULATA, *Goepp.*, Gen. d. pl. foss. 5-6, tab. 13, et tab. 9, f. 12 and 13. OBTUSA, *Brongn.*, tab. 78, f. 3 and 4.

48. O. HETEROPHYLLA, *Lesqr.*? Geol. Surv. of Illinois, pl. 38, f. 1-5.

49. O. BRARDII, *Brongn.*? tab. 76. A large single leaf, pl. 12, f. 4.

This is a single leaf of a large specimen allied to O. Brardii, *Brongn.* The plant from which it became detached must have far exceeded in size any of the specimens figured.

50. ODONTOPERIS NEUROPTEROIDES, *Marrat*, pl. 7, f. 1-2.

Frond broadly lanceolate, bipinnate, pinnules oblong, obtuse, the terminal confluent, the lateral decurrent, the terminal pinnule of the lateral pinnæ lanceolate, lobed, sometimes auriculate, rachis rather strong, nerves furcate, passing into the rachis and striating it.

CALLIPTERIS, *Brongn.*

51. C. CONFERTA, *Sternb.* (?)

PECOPTERIS GIGANTEA, *Brongn.*, tab. 92. (?)

Our plant differs from all the figured specimens in having the pinnules detached and rather distant. In its nervation it closely resembles Brongn.'s figure of the magnified leaf, being more that of a Neuropteris than a Pecopteris. The pinnules are decurrent, but not confluent.

ORDER III.

PECOPTERIDEÆ.

PECOPTERIS, *Brongn.*

PECOPTERIS, *Cyatheides.*

52. P. ARBORESCENS, *Scloth, Brongn.*, tab. 102 and 103.
var. cyatheus, tab. 101, f. 1-3.

53. P. DENTATA, *Brongn.*, tab. 123 and 124.
var. PLUMOSA, *Brongn.*, tab. 121 and 122.

54. P. MILTONI, *Artis*, tab. 14.

55. P. POLYMORPHA, *Brongn.*, tab. 115, f. 1 to 4.
var. P. ABBREVIATA, *Brongn.*, tab. 115, f. 1-4.

PECOPTERIS, *Aspidides.*

56. P. NERVOSA, *Brongn.*, tab. 95, f. 1 and 2. *Lindl.* and *Hutt.*, tab. 94.

57. P. MURICATA, *Brongn.*, tab. 94, f. 3-4.

58. P. ÆQUALIS, *Brongn.*, tab. 118.

ALETHOPTERIS, *Sternb.*

59. A. LONCHITICA, *Brongn.*, tab. 84, var. heterophylla, *Lindl.* and *Hutt.*, tab. 38, var. MANTELLI, *Brongn.*, tab. 83.

60. A. SERLII, *Brongn.*, tab. 85, var. with the terminal lobe acute.

61. A. DECURRENS, *Dawson*, Quart. Journ. Geol. Soc., vol. 18, pl. 2, f. 1—3.

62. A. OBLIQUA, *Brongn.*, tab. 96, f. 1 to 4.

LIST OF PALEONTOGRAPHICAL WORKS IN THE LIVERPOOL FREE PUBLIC LIBRARY, REFERRED TO IN THE DESCRIPTION OF THE FERNS IN THE RAVENHEAD COLLECTION.

Brongniart's Histoire des Vegetaux Fossiles, 15 parts, all published.

Lindley and Hutton's Fossil Flora of Great Britain, 3 vols.

Parkinson's Organic Remains, 3 vols.

Artis' Antediluvian Phytology, 1 vol.

Quarterly Journal of the Geological Society.

Annals and Magazine of Natural History.

Lesquereux' Geological Survey of Illinois, Vol. II., Paleontology.

The Publications of the Paleontographical Society.

Goeppert's Fossilen Farrnkràuter, 1 vol. quarto, with 44 plates.

Morris's Catalogue of British Fossils.

Dana's Geology.

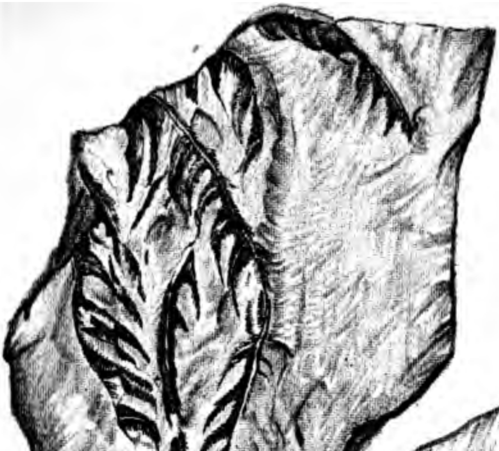
Schimper's Traite de Paléontologie Végétale, 2 vols. 4to., with Atlas of plates.

The Monthly Microscopical Journal.

REFERENCE TO PLATES.

Plate 1, f. 1.—Nephropteris (Neuropteris) triangularis, *Marrat.*

„ f. 2.—Rootstock of a Fern, with paleæ or chaffy scales.



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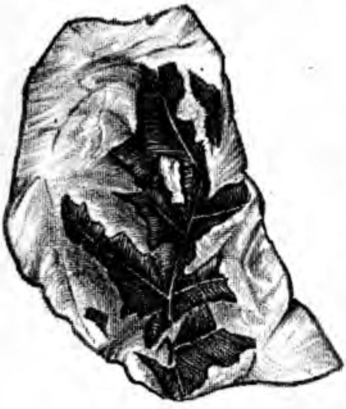

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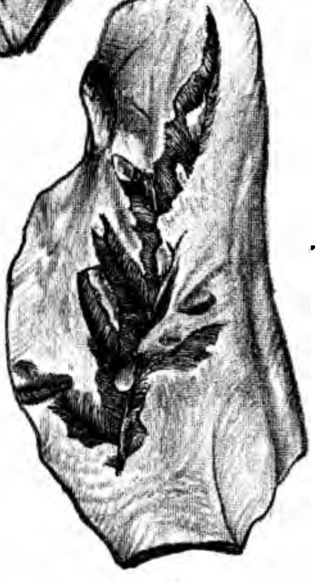

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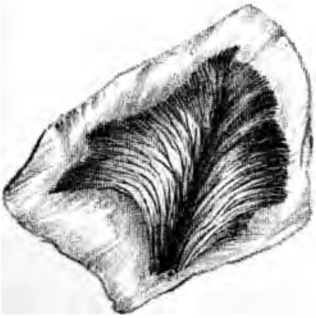

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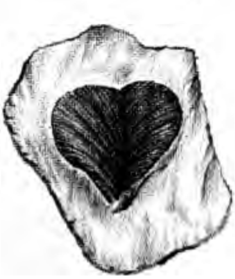

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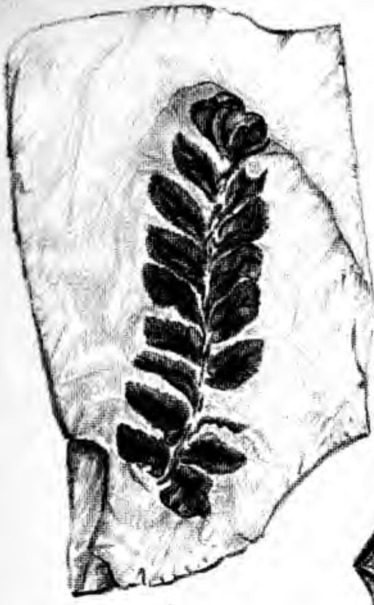
PLATE 2, f. 1—3.—Alethopteris decurrens, *Dawson*.
„ f. 4.—A leaf in which the nerves coalesce, probably one of the lower leaflets of Neuropteris hirsuta, *Lesqr*.
„ f. 5.—Neuropteris obcordata, *Marrat*.



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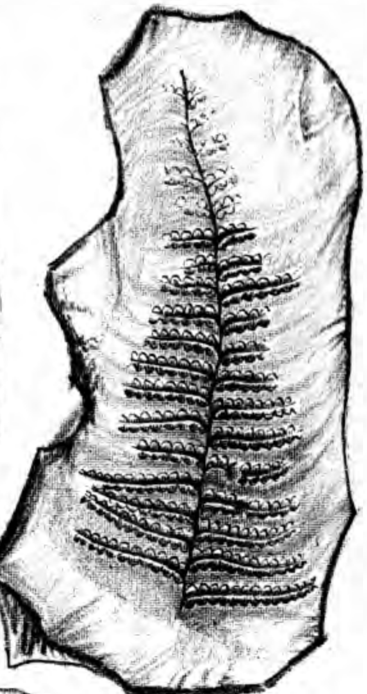

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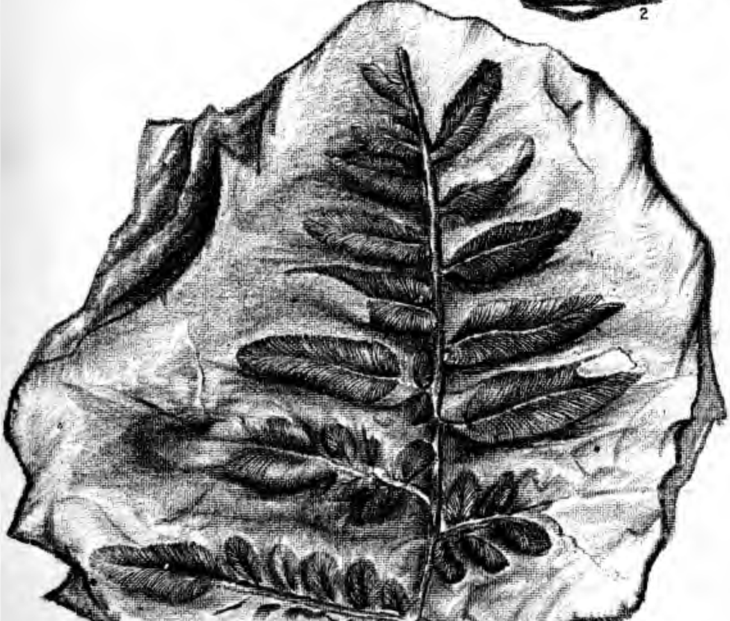

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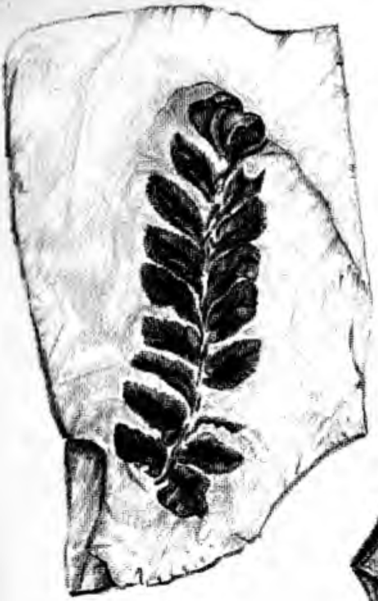
Plate 3, f. 1.—A curious pinna, with a cluster of terminal pinnules (Neuropteris.)
„ f. 2.—Pecopteris æqualis, *Brongn.*, pl. 118, f. 2.
„ f. 3.—Neuropteris heterophylla, *Brongn.*, var. (?)



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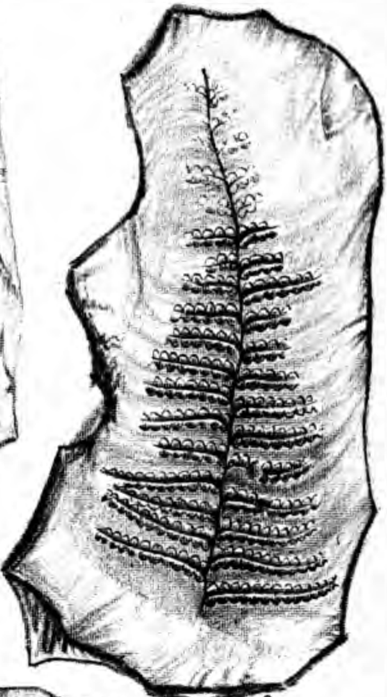

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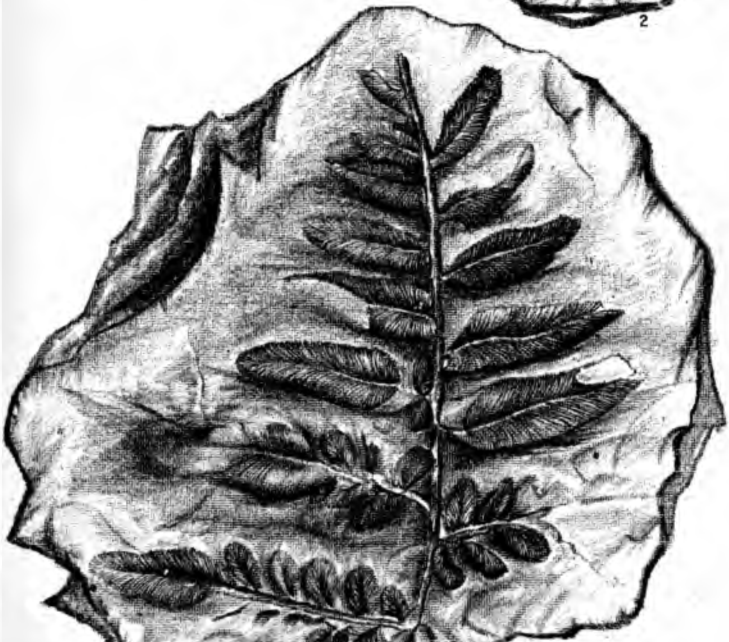

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PLATE 4, f. 1—5.—Sphenopteris (Hymen.) spinosa, *Goepp.*
„ f. 2.—A curious lobed form.
„ f. 6.—Sphen. (Davall.) palmata, *Schimp.* terminal pinnæ.

PLATE 5, f. 1—2.—Sphen. (Trichomanoides) dissecta, *Brongn.*, var.
„ f. 2 A.—A magnified leaf.
„ f. 3.—Sphen. (Cheil.) plumula, *Marrat.*
„ f. 3 A.—A magnified leaf, showing nervation.
„ f. 4.—Sphen. (Trichomanoides) multifida, *Marrat.* Showing the drooping upper fronds.
„ f. 4, A B.—Magnified leaves, showing nervation.
„ f. 5.—Sphen. (Hymen.) curtiloba, *Dawson*, var., in ironstone.
„ f. 5 A.—A magnified portion of a pinna.

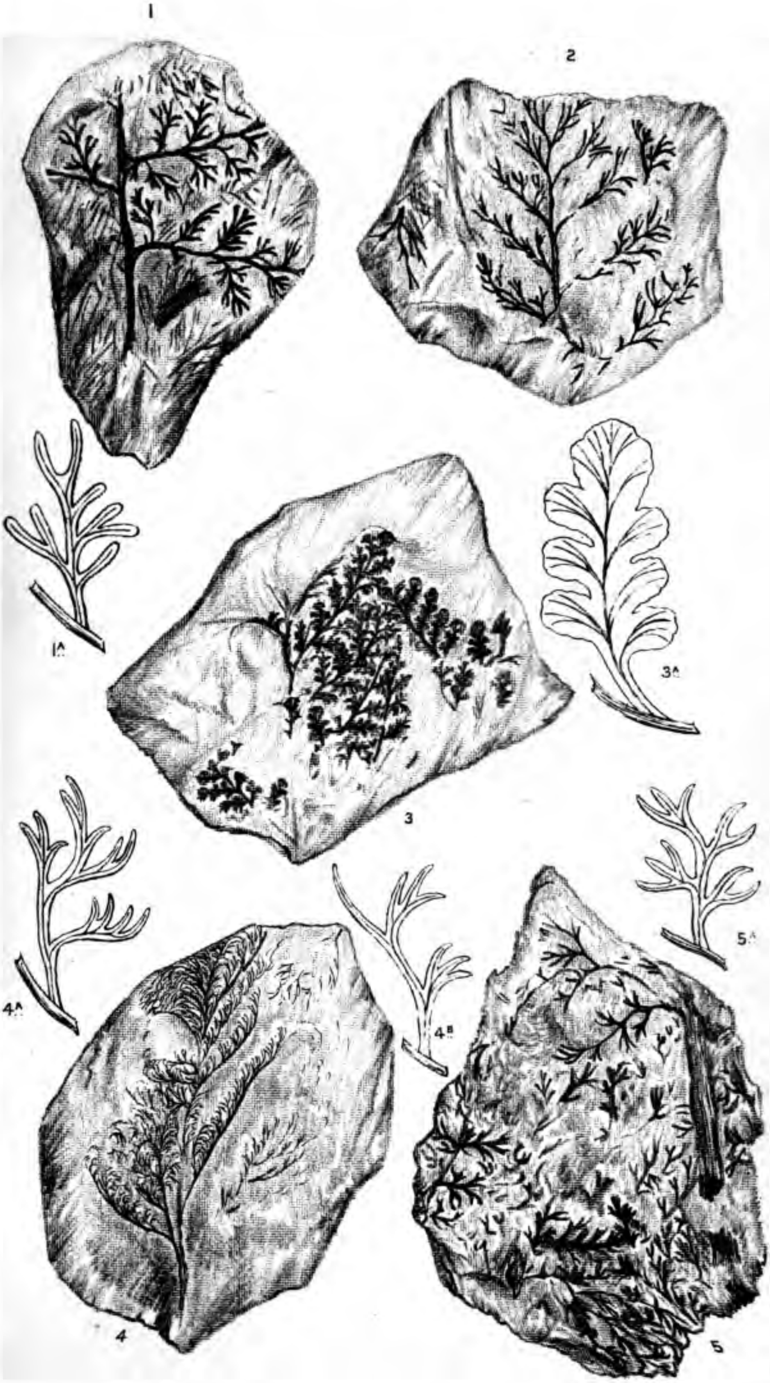
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PLATE 6, f. 1.—Neuropteris heterophylla, *Brongn.*, var. (?)
,, f. 1 A.—A magnified pinnule, showing nervation.

PLATE 7, f. 1—2.—Odontopteris neuropteroides, *Marrat.*
„ f. 2 A.—The end of a lateral pinna.
„ f. 2 B.—A lateral pinnule magnified, showing bifid nervation.

PLATE 8, f. 1.—Sphen. (Aneimioides) pulchra, *Marrat.*
,, f. 1 A 1 B.—Magnified pinnules of the same, showing striation and nervation.
,, f. 2—3.—Sphen. (Hymenophyllum) Footneri, *Marrat.*
,, f. 3 A.—A magnified pinnule, showing nervation.
,, f. 4.—Circinate foliage of the same plant?

PLATE 9, f. 1.—Sphen. (Gymno.) coriacea, *Marrat.*
„ f. 2.—Upper portion of the same.
„ f. 2 A.—A magnified pinnule of f. 2, showing nervation.
„ f. 3. Sphen (Cheil.) obliqua, *Marrat.*
„ f. 3 A.—A magnified pinnule.
„ f. 4.—Odontopteris heterophylla, *Lesquereux*, var. (?)
„ f. 5.—Ditto.

Plate 10, f. 1.—A stem allied to Caul. Worthenii, *Lesq.*

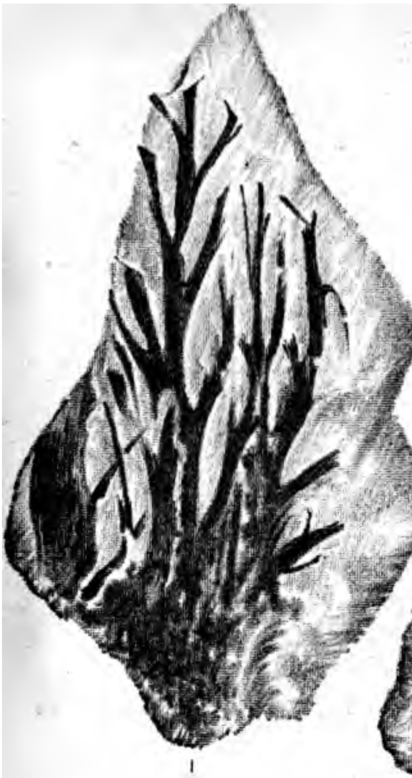
PLATE 11, f. 1.—Stem of a tree fern.

" f. 2—f. 2 A—f. 2 B.—Portions of the stem of a tree fern, showing adventitious roots.

PLATE 12.—f. 1—2.—The upper and lower portions of a leaf of Nephropteris.
„ f. 3.—A leaf of Neuropteris heterophylla, intermediate in size between the leaf figured by *Lindl.* and *Hutt.*, pl. 183, and the plant, figured at pl. 6.
„ f. 4.—A large leaf of Odontopteris Brardii.
„ f. 5.—A young fern, just unfolding its leaves.
„ f. 6.—A leaf of Neuropteris, of which there are two similar specimens in the collection.
„ f. 7.—A young fern, covered with fine hair-like paleæ.
„ f. 8.—Callipteris conferta, *Sternb.* (?)
„ f. 8 A.—A magnified leaf of the same plant, showing the nervation.

Plate 13, f. 1—3.—Plants of doubtful affinity: possibly Algæ.

These lithographic drawings have been executed by Mr. J. Chard, of the Free Public Museum, Liverpool.



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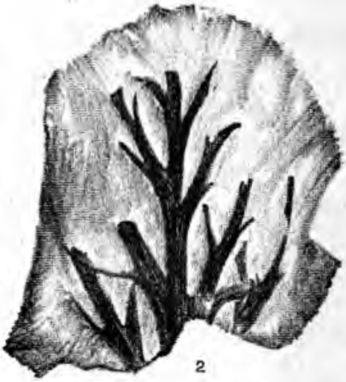

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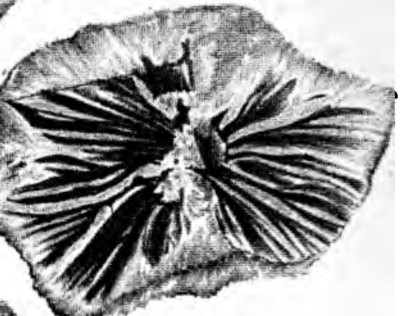

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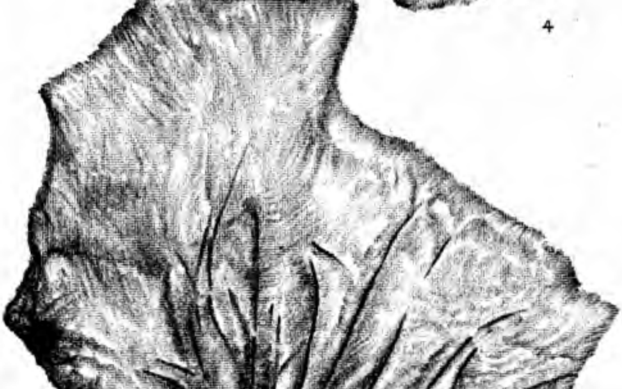

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NOTE ON THE SIVATHERIUM OF THE UPPER MIOCENE OF THE SIVALIK HILLS, AND ITS SUPPOSED ZOOLOGICAL RELATIONS, AS ELUCIDATED BY DR. JAMES MURIE.

By Thomas J. Moore,

(Curator of the Free Public Museum, Liverpool.)

The object of this communication was to bring before the Society some of the more important specimens possessed by the Free Public Museum, serving to illustrate the huge four-horned, proboscidian-like Ruminant, from the Sub-Himalayas, described and named by the late Dr. Falconer and the late Sir P. Cautley under the name of *Sivatherium giganteum,* one of the rarest and most remarkable of their many discoveries in that region.

The chief light thrown by Dr. Murie on the affinities of Sivatherium is derived from a study of the recent Pronghorn Antelope of North America *(Antilocapra)* and the Saiga Antelope of Tartary; the faceal bones of the latter agreeing closely with those of Sivatherium, and the unique characters of the horns of the Prongbuck seeming to approximate to the peculiarities in the hinder horns of Sivatherium.

In addition to a full set of coloured casts of almost all the known remains of Sivatherium, and some few real, though fragmentary bones of the same, the Museum contains stuffed specimens and skulls of the adult male, female, and young of the Saiga; the skull and stuffed head of the Prongbuck, shewing well the peculiar mode of casting the sheaths of its horns, as well as other specimens, serving to elucidate the excellent paper "On the Systematic Position of the *Sivatherium giganteum* of Falconer and Cautley, by Dr. James Murie, F.G.S., F.L.S., &c," read at the meeting of the British Association held at Edinburgh, and published, with illustrations, in the *Geological Magazine* for 1871.

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SESSION THE FOURTEENTH,

1872—73.

(The Authors having revised their papers, are alone responsible for the facts and opinions expressed in them.)

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ABSTRACT OF THE PROCEEDINGS
OF THE
LIVERPOOL GEOLOGICAL SOCIETY.

SESSION FOURTEENTH.

OCTOBER 8TH, 1872.

Anniversary Address by the President, CHARLES RICKETTS, M.D., F.G.S.

GENTLEMEN,

WHEN I had the honour of addressing you at our last anniversary meeting, I directed your attention to some of the physical changes which appear to be dependent upon valley denudation, especially to the effects resulting from the deposition, at and near their deltas and *in the neighbouring seas*, of the materials which have been abraded from the sides of valleys and carried down by rivers; thus causing, by its weight, depression of the land. It is my intention to consider the further effects of this depression and of its converse elevation of the land, in the production of fissures, fractures, and faults; also the influence which the presence of valleys and faults may have in inducing contortion and slaty-cleavage.

Upon the former occasion it was proved that by no possibility could river-valleys have been excavated by the action of the sea, nor be attributed to any other cause than that of subaërial agencies alone (including under that term ice and glaciers); in this agreeing with the opinions of Hutton and Playfair, as well as a large and increasing body of geological observers. I dwelt especially upon the evidences of subsidence occurring so frequently near the mouths of large rivers, showing that there the deltal accumulations are often of immense thickness, as proved by borings that have been made to great depths and through successive ancient land surfaces; also that bays are formed in situations where, taking into consideration the enormous amount of material which has been removed from the areas constituting valley basins, and has been brought down by the rivers traversing them, there must, had no such subsidence taken place, have existed alluvial plains, extending for immense distances into what is now the sea. A similar depression was also shown to have occurred in Palæozoic formations, evidences of deposit in shallow water being constantly found at or near their base, superimposed on which the strata rest conformably, it may be, even to the thickness of several miles; proving that, simultaneously with the accumulation, depression must have occurred in these localities to at least that extent. It was contended that this subsidence was a consequence of the weight of these deposits pressing downwards the crust of the earth. As a consequence of subsidence in one place, there must of necessity be elevation in another. Elevation would also result from the removal of pressure; but the subject was not much dwelt upon, the chief evidence adduced being the partial re-elevation of the land upon the removal of the great ice-sheet of the glacial period. It is likewise evident that those strata, which in continents, &c., are situated highest above the sea-level, forming hills and mountain ranges, are often geologically the lowest in the series—appearing to indicate that upheaval of the earth's crust has occurred to the greatest extent where the largest amount of material has been removed by denudation to form these mountains.

These innumerable evidences of changes of level—in some cases of elevation, in others of depression of the land—occur in all parts of the globe; they date from the earliest period registered in the geological record, and extend down to the present time. I cannot conceive how their occurrence can be so general, or that they should be so continuous and gradual in their progress, if the interior of the earth is not to a certain extent in a state of fluidity, and covered only by what, compared with the whole mass, must be a thin crust. The results of borings to great depths, for mining purposes and in well-sinkings, show a progressive increase of temperature with increasing depth, the amount varying in different localities.

Humboldt remarks in his 'Cosmos,' that "tolerably accordant experience has shown that in Artesian wells the average increase of temperature in the strata pierced through is 1° of Fahrenheit for 54.5 feet of vertical depth; or, if we suppose this increase to continue in an arithmetical ratio, a stratum of granite would be in a state of fusion at a depth of nearly twenty-one geographical miles, or between four and five times the elevation of the highest summit of the Himalaya."*

Both Professors Phillips and Ramsay consider the real temperature of flowing lava to be 2,000° Fahr., and that is the estimate of the temperature of its bright red mass at which Mr. Mallet arrived from an inspection of the crater of Vesuvius when in eruption. This calculation, according to the ordinary method of computation, agrees sufficiently nearly with the estimate of the depth of fluidity made by Humboldt.

Others, whose opinions must always command attention, do not accept this view of the fluidity of the earth's interior, or they consider that it does not occur at such comparatively slight depths. From astronomical and mathematical calculations, dependent upon the precession of the equinoxes and the nutation, Mr. Hopkins estimated the depth of solidity at 600 or 800 miles; and Archdeacon Pratt considered that he has shown that the *slowness* of the motions of precession and nutation can in no way justify the supposition that the interior of the earth, were it a viscous fluid, would move exactly as the solid crust does; that pressure has turned what was liquid at a certain temperature into a solid rigid mass at a lower temperature; and the result is that the interior is solid, not fluid.* But arguments advanced by Mons. Delaunay show that, as the rotary motion imparted to the solid crust by the actions of precession and nutation is one of extreme slowness, and has to unite itself with the movement of rotation which it already possesses, there cannot, in his opinion, be the least doubt that the fluid mass which constitutes the interior of the globe must follow along with the crust that confines it, exactly as if the whole formed a solid mass throughout. To confirm these views by direct investigation, Delaunay caused experiments to be made "which remove every possible doubt on the subject."†

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* Sabine's Edition, p. 163.

Mr. G. Powlett Scrope, whose works have long been recognised as the most reliable text-books upon all subjects connected with volcanic phenomena, doubts whether the substratum is generally liquefied, and considers that the occurrence of elevation may be equally explained by the transference, not of liquid matter, but of heat from one part of a solid substance to another, and that the cause of the transference is not so much variation of pressure as of obstruction to the passage of heat on account of its more or less imperfect conduction, owing to the accumulation of sedimentary strata above.* He considers that the particular point on which the whole theory hinges is the enormous *pressure* to which every portion of the heated interior of the globe must be subjected; and this not merely from the weight or contraction of cooling of its outer belt, but also from the vast internal tension of its every part, caused by its tendency to expansion through intense heat.† Assuming that this compression will prevent the liquefaction of a solid in the same way that it prevents the vaporization of a liquid.

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* "The Crust of the Earth cannot be thin."—*Philosophical Magazine* 1871, vol. xlii, p. 289.

† "On the Internal Fluidity of the Earth."—*Geological Magazine* 1868, vol. v, p. 507.

Though compression will prevent water and other liquids from passing from a fluid state to that of vapour, can it be proved that it will in a similar manner prevent a solid from becoming liquid, or cause a liquid to become solid? The only substance which ordinarily in a fluid state is subjected to a pressure, at all comparable to that of the substratum of the earth, is salt water at the extreme depths of the ocean; but the lead has never reached a bottom where the water does not remain fluid. Sea-water, unlike fresh water, "continues to contract, and, therefore, to increase in density," as its temperature decreases down to its freezing point, 27.5° to 25.5° Fahr. It has been recently proved that the temperature, as shown by protected thermometers, is 32.5° Fahr. in soundings recently taken under the Equator, at a depth of 2,000 fathoms; and Dr. Carpenter considers that if soundings are made deep enough in Equatorial seas the temperature, as a consequence of the underflow of Polar water towards the

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* "Volcanos," p. 274.

† *Geological Magazine*, 1868. vol. v, p. 538.

Equator, will invariably be found to be glacial.[*] If this low temperature exists at the extreme depth of 4,600 fathoms, or nearly 5¼ miles, to which the lead has been sunk without finding soundings in the Atlantic Ocean, somewhat south of the Equator,[†] sea-water, having a temperature within 5°, or at the most 7° of its freezing point, is there exposed to a pressure amounting to nearly six tons to the square inch, without congelation taking place.

Some have argued that, in "the process of cooling, condensation or congelation would commence at the centre and extend outwards toward the surface, so that the temperature of the centre would, therefore, be the temperature of congelation."[‡] There is one insurmountable objection to this; when the fluid interior of the earth finds its way to the exterior in the shape of lava, it has the property of congealing at its *surface*, whilst its interior portion still remains fluid, and continues to flow long after the outside has become solid and stationary.

It is very generally conceded that the effect of elevatory force must be to raise the mass under which it acts, placing it in a state of extension, and consequently of tension. As the upheaval continues, this strain will increase and become sufficient to rupture the strata, producing fissures, even extending through the whole thickness of the earth's crust. To the presence of such fractures the occurrence of the volcanoes of the Andes may be attributed. But a similar result has not so frequently been ascribed to the effect of subsidence, though tension and extension, and therefore fissures, must occur under such circumstances, commencing from a depth coinciding with that of the chord of the arc of the earth's circumference included within the subsiding area. That such fissures do occur in areas which are those of depression, is proved by volcanoes being frequently situated in such localities, some of which are known by observation to be subsiding; for instance, the Andaman Islands have been computed to be sinking at the rate of a foot in a century, and in the immediate vicinity is the active volcano of Barren Island, the visible commencement of a great fissure extending through the Indian Archipelago, in which "the single island of Java contains a larger number of active volcanoes than any other district of equal extent on the face of the globe." South of the Philippine Islands this fissure is met by another, which—as is rendered evident by the numerous volcanoes along its course—commences at Kamschatka, and passes through the Japanese Islands parallel to the coast-line of Eastern Asia: the two joining, extend by the Fiji Islands as far as New Zealand. The direction which the northern portion of this fracture takes is along a coast, which if you accept as proved the proposition I advanced at the first meeting of last session, must be one of subsidence; evidenced by the alluvial plains and bays which have resulted from the accumulation and pressure of the enormous amount of sediment brought down by the rivers which drain the eastern part of Asia. The occurrence of Trappean rocks is also very frequent in Palæozoic formations, lying, as in the Lower Silurian strata of North Wales, and in the Old Red Sandstone and Carboniferous of the neighbourhood of Edinburgh, interstratified with the sedimentary deposits; they were at their respective periods erupted and poured forth, either as volcanic ashes or lava-flows, in areas which were at that time generally if not entirely submarine—at all events, which were subaqueous, and, as is proved by the large amount of subsequent accumulations, also *subsiding.*

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[*] "The Temperature and other Physical Conditions of Inland Seas;" read before the British Association, section C, 1872; reported in *Brighton Daily News*. The temperature recorded by Prof. Wyville Thomson as the result of soundings lately taken in the Atlantic during the 'Challenger' expedition, is somewhat higher than that given by Dr. Carpenter. The average of five, at depths of 2,000 fathoms and upwards, amounted to 1.82° Cent., or 35.27° Fahr.—*Nature*, 1873, vol. viii, pp. 28—51.

[†] A. K. Johnston's "Physical Atlas."

[‡] Dr. T. Sterry Hunt, "Chemistry of the Primæval Earth."—*Geological Magazine*, vol. iv, p. 361.

An examination of Trappean dykes tends to prove that the molten rock "has been forced up through previously-formed fissures to a certain height;" in its passage baking, but not disturbing, the rocks which form the walls of the fissures; but in the case of volcanoes in subsiding areas, and where there is a great deposition of sedimentary matter, this can only occur so far as the fracture extends upwards, that is, so far as the chord of the arc before referred to; because there is near the surface, as a consequence of the depression, some tendency to lateral pressure, causing a certain amount of compression instead of tension. In some cases, at least, where it is probable that volcanic eruptions have taken place through contemporaneous rocks, it appears as if, in the formation of the vent of the volcano, a portion of the strata through which it passed has been blown away, probably by the explosion of vapours, &c.; for it occasionally happens that there is no appearance of fracture or fault extending from the pipes to a distance into the sedimentary rocks. Nor is this inconsistent with the general sequence given of volcanic phenomena, which more frequently commence with a great explosion of steam and gases, carrying upwards immense quantities of scoriæ and ashes, and not unfrequently blowing off the summits of cones which had been formed by previous eruptions. This state, after continuing for a time, is followed by a flow of lava, which "sometimes wells out with the tranquility of a water-spring from the same or contiguous openings." The explosive eruptions appear to be caused by water, derived from springs, from the sea or other sources, flowing into the clefts in the rocks and coming in contact, at a greater or less depth beneath the surface, with the incandescent lava which has found its way upwards through fissures; the vapour thus formed explodes and carries upwards portions of the molten rock, in the form of volcanic bombs, ashes, and dust, in a manner similar to that in which a metal melted in a crucible is forcibly thrown out by the sudden formation of steam, if water is allowed to drop amongst it. I think I may claim that this opinion coincides with that of Professor Phillips, to whom there seems no reason to doubt that the evolution of steam takes place very frequently from the surface or the upper part of a mass of lava within the crater.* The peculiar conical form of volcanic mountains arises from the accumulation of ashes, scoriæ, &c., which, after being forcibly ejected by the explosion of steam and gases, fall downwards around the opening, and spread out laterally in every direction, until its sides form such an angle as the particles are enabled to assume in a position of rest.

The lava-flow appears to be chiefly dependent for its egress upon the force of gravitation pressing it upwards, until it can find a vent for its escape; it may be from the crater itself, but in preference from a fissure situated at a lower level.

In the formation of volcanic dykes the molten rock has passed upwards without disturbance of the contiguous strata. More remarkable has been its intrusion between beds. However powerful has been the force which has produced this effect, there is, in innumerable instances, no indication of violence. Belts of Green Stone or Basalt have been intruded—it might be better to say insinuated—between the strata so completely in the direction of the bedding, and with so little disturbance, that, were it not that the strata have been altered by heat above as well as below, it would be with great difficulty—sometimes, perhaps, not at all—possible to decide whether these igneous rocks were interstratified, and therefore contemporaneous with the beds, or had been forced between them subsequently.

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* "Vesuvius," p. 145.

There is much proof of a local connexion between volcanoes and earthquakes; both are developed oftentimes along the very same linear bands, or about the same insulated spots upon the surface of the globe; eruptions of the former being generally preceded, and are often accompanied, by earthquake-shocks. But earthquakes are far from being confined to the neighbourhood of volcanoes; the Himalayas and the enormous table land of Central Asia are very liable to earthquakes of fearful intensity; the Alps and Pyrenees are frequently shaken; so, also, the non-volcanic basin of the Baltic and the valley of the Mississippi are very subject to them, though far removed from any volcano.* Earthquakes appear to be prevalent in situations which there is reason to conclude are either areas of elevation or else of depression. Mr. Scrope considers that volcanoes and earthquakes are manifestations of a common subterranean force, acting under different conditions, believing that the greater earthquakes proceed from efforts of subterranean expansive force taking place at too great a depth and under too vast a mass of overlying rocky matter to effect that free communication with the air to admit of the development of volcanic phenomena;† that the snap caused by the creation of fissures would occasion those sensible superficial vibrations through the adjoining and overlying rocks which we call earthquakes;‡ that all earthquake shocks, whether on the largest or the smallest scale, are occasioned by the jar and vibration propagated through the contiguous rocks by the splitting of fissures.* Mr. Mallet considers that they often arise from deep subterraneous volcanic action, and also from the breaking up or the grinding over each other of rocky beds at a great depth through the tangential pressures produced in the earth's crust by secular cooling.† Humboldt attributed the slight and perfectly harmless tremblings of the crust of the earth accompanying volcanic eruptions, and lasting for several days, to elastic fluids subjected to enormous pressure.‡

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* Scrope, "Volcanos," p. 8. † Page 9. ‡ Page 288.

Should considerable and sudden fissures take place in any rock mass, it is to be expected that earthquakes would necessarily ensue. Local shocks also occur during volcanic eruptions, producing tremblings in the mountain, apparently caused by the explosion of the heated vapours, such as Humboldt speaks of as occurring periodically from twenty to thirty seconds before the eruption of incandescent scoriæ or gases, and which he felt whilst standing at the edge of the crater of Vesuvius, and on the towering cliff which rises above the great abyss of the crater of Pinchincha, near Quito.

Those who have paid the greatest attention to earthquake phenomena appear entirely to overlook the geological changes produced by faults, each of which must be a register of at least one, and many in all probability record a succession of earthquake shocks, notwithstanding that many of the accounts of recent earthquakes present changes in the surface of the land which are analogous to faults in strata; the sudden depression in level in one portion, as if it had been fractured and had fallen down, whilst the other has remained stationary. But the converse appears generally to happen with those earthquakes which occur upon the west coast of South America, where the accounts of the movements by which they are accompanied indicate that they are due to sudden elevation of land.

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* Scrope, "Volcanos," p. 50.

† *Quart. Jour.* Geological Society, 1872; Discussion, vol. xxviii, p. 270.

‡ "Cosmos" (Sabine's Edition), vol. i, p. 201.

Previous to a fault being formed, a fissure must have taken place in the crust of the earth, and have progressed so as to cause a greater or less interval between the sides of the fissure. This, as has been explained, will occur either upon depression or elevation of the surface, increasing as the elevation or depression becomes greater. Should there be a stratum so far unconsolidated that it cannot support the pressure of the overlying beds, (as the rocks having lost their lateral support by the separation of the sides of the fissure,) the result must be that wedge-shaped masses will separate and fall or slip downwards, in a manner similar to what occurs to a block of masonry, however solid, should its foundations be undermined; or, in the same manner, but on a much larger scale, as that of the landslips along our coasts, only that in faults the wedge-like mass is checked when it comes in contact with the opposite side of the fissure, causing that thud or blow which occasions the vibration of the earth's surface and constitutes the earthquake. It is not improbable that, in some cases, the fracture will extend through the whole thickness of the earth's crust, even to the partially molten interior.

There are none of the phenomena which are described as attending the greater earthquakes, which may not be accounted for by referring them to those changes which are seen to have taken place in the formation of faults; whilst it is probable that minor shocks may be attributed to inconsiderable movements along the same lines of fracture, or to those minor faults which so constantly attend the production of the larger. It may be expected that, if the method is followed up which Mr. Mallet adopted, with such wonderful perseverance and success, with respect to the Neapolitan earthquake of 1857, viz., by a careful examination of the effects upon buildings, &c., and tracing them backwards to their source, the result will prove that these shocks have been dependent on the occurrence of dislocations, similar to what geologists and miners call faults; as it is many such are upon record, but the tendency with most persons appears to be to attribute them to the effects of the earthquake, and not the earthquake to the effects of the dislocation.

The only fissures which take place as the *effects* of an earthquake shock are superficial ones, generally occurring in unconsolidated strata; "the necessary condition of the production of a fissure thus brought about being," as Mr. Mallet remarks, "that, of the earth-masses at either side of the fissure when formed, one or other shall have been, relatively to the other, free in one direction." An excellent example of these secondary effects of an earthquake occurring under such conditions is recorded in the *Quarterly Journal* of the Geological Society for 1872,* being a description, in a letter by Dr. Oldham, F.R.S., of the results of the earthquake of Cachar, in Eastern India, on the 10th of January, 1869. The loose unconsolidated flat through which the river in its course has cut deep channels, forming banks from thirty to fifty feet high, being thus unsupported along the river channels, upon the occurrence of the earthquake shock all slipped in towards that channel, producing enormous fissuring in all cases corresponding with the general curve of the stream adjoining. These fissures were traced as extending down the river for more than a hundred miles.

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* Vol. xxviii, p. 255.

Few, if any, will now believe that any great faults are the result of one single movement, but are rather to be attributed to a long succession of displacements; and it is likely that some do not through their whole extent belong even to the same geological era. Faults not unfrequently have caused an enormous displacement of the strata; Prof. Ramsay calculates that some in North Wales represent a dislocation of 2,000, 5,000, or even 12,000 feet. Enormous wedge-shaped masses, such as in these cases have fallen downwards and filled up what would otherwise have been extensive chasms in the earth's crust, have increased, to so great an extent, the superfices of its surface.

This displacement or downthrow, which occurs in the event of a fault being formed, is simply a falling or slipping downwards of separated rock-masses along planes of fracture; and it is evident that the strata cannot by that movement become bent or contorted, nor can the original direction of the dip be altered; but the portion which is depressed must continue in the same direction as that from which it has been separated, and, after falling, will necessarily retain this position; for the mass is prevented from tilting over in consequence of the impulse being checked by the opposite wall of the fissure. Even in ordinary landslips, where there is nothing to restrain the shock, it is often remarkable how little the beds have been disturbed from their original direction. Bendings of the strata and other alterations in the angle of the dip, occurring in the neighbourhood of faults, by which their direction has been made to differ from those adjacent, have therefore been caused since the occurrence of the displacement, and will have been dependent upon forces which have arisen subsequently.

Slickensides, or friction surfaces, caused by the rubbing together of the sides of fissures, &c., in rock masses, are frequently met with in connexion with faults, and indicate the direction of some movement which has taken place. They may sometimes have been caused by the friction induced at the time of the occurrence of a fault; but in such a case, the striations could only have been in a direction downwards along the hade of the fault. This is that which the marks generally take in the case of the principal, *i.e.* the north and south faults of this district; but as the strata have, subsequent to their formation, been exposed to compression at right angles to the faults, it is to the latter circumstance their presence must be attributed, for the action of the second movement would obliterate any that might have been induced by the first. In those having an east and west direction, or nearly approaching it, the slickensides are sometimes nearly horizontal, in others, and more frequently, they are more or less oblique, and seem to indicate, in the one case, that there has been a lateral movement, in the other that, as well as this, there has been at the same time an amount of upward pressure. This oblique direction in the striations is very frequent in the Lower Keuper formation which overlies the soft red sandstone of the Upper Bunter, and in the Upper Bunter itself. As the lateral pressure, by which these triassic rocks have been acted on, has been in an east and west direction, the tendency would be to compress into a less lateral compass, in the same direction, the slightly consolidated beds of the Upper Bunter Sandstone, and, by causing a re-arrangement of the particles of which they consist, or by inducing foldings of the beds, occasion to a certain extent an elevation of the superincumbent strata; the movement thus induced would cause that friction along the sides of faults by which their surfaces have become polished and striated.

Slickensides also occur in fissures where there has apparently been no alteration, or very little, in the level of the beds. They may be very frequently observed in the Palæozoic formations of Wales. Numerous examples are to be seen in the Ash-bed with Volcanic Conglomerate at the entrance to Calton Hill, Edinburgh. They are not infrequent between beds, where there is a considerable bending in hard sandstone or other rocks, as the anticlinal on either side of Llyn Padarn, Llanberis. In these cases the phenomenon may be satisfactorily explained by attributing the agencies by which it has been caused to lateral pressure, or to slight changes of position, under similar pressure, during the bending of one stratum over another after it has become consolidated.

The explanation I have given for the production of slickensides whose striæ run obliquely, will be sufficient to account for the occasional occurrence of what are called "reversed faults" in this district, or at least of one of them. These are so rare that the late Professor Jukes, in his Student's Manual of Geology, 1862, stated that he had never met with an example; but our Secretary, Mr. Morton, has described one which was formerly exposed in Liverpool,* and Mr. Bostock has referred me to another in the Railway Cutting near Orrell. One forming a trough fault occurs at Tollemache Road, near the Birkenhead Cemetery, where the strata upon what in ordinary cases is the "downthrow" has been elevated about 7 or 8 feet. The uppermost beds form the base of the comparatively hard Lower Keuper Sandstone, and is seen overlying the soft mottled sandstone of the Upper Bunter. It is not probable that the position in which this fault now is, could be its original one, but that it has been elevated from the ordinary "downthrow" that faults occupy in consequence of lateral compression, squeezing together the soft underlying sandstone, causing the beds to become thicker, perhaps somewhat contorted, and thus raising a fault having no great throw, somewhat above its original level. There is evidence here of lateral pressure not only from the occurrence of oblique slickensides in the immediate neighbourhood (in the quarry close to the Cemetery boundary), but also in the fault itself. The spaces which intervene between the sides of the faults are filled with what I have heard called "fault-rock," that is, the material which has resulted from friction or which has been introduced subsequently to the formation of the fault. This, instead of forming horizontal or nearly horizontal layers, as it would have done when first deposited, has been re-arranged in laminæ, parallel to that of the hade of the fault. This lamination of "fault-rock," comparable in some respects to a kind of coarse cleavage on a limited scale, is very common in the north and south faults, and its production may be attributed to the action of a cause similar to that of cleavage—lateral pressure.

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* *Liverpool Naturalists' Journal.*

It is self-evident that contortions and flexures of stratified rocks could not have occurred at the time of their tranquil deposit; and it is almost as certain that extensive foldings cannot be attributed to the same causes which have induced the formation of faults, and of those fissures which now constitute mineral lodes, or which, filled with Greenstone and Basalt, form volcanic dykes; for we have seen that the strata must have been exposed to tension to have produced these fissures, and, the extension continuing, has caused a separation of their walls, which, under certain conditions, has induced those fractures and dislocations called faults. To illustrate the manner in which contortions have been formed, Sir James Hall, in 1813, showed that they were readily imitated by placing alternate layers of clay, or pieces of differently-coloured cloth, and causing lateral compression by forcing the two ends nearer to each other, thus pressing the strata more closely together laterally, but elongating and making them to rise upwards in a direction perpendicular to the pressure. Even in hard and consolidated rock, flexures can take place to a considerable extent, as was lately proved experimentally by Mr. L. C. Miall, of Bradford;* but it is to be regretted that he has not imitated what appears to be the process which nature adopts, and applied pressure laterally, instead of in a direction perpendicular to the surface.

The opinion of Sir J. Hall has been very generally accepted by geologists, some even admitting the principle who attribute these foldings of strata to the unaided effect of upheaval alone, but "that would stretch instead of crumpling the surface," and, therefore, contortions under such circumstances would be impossible. Nevertheless, the occurrence of contortions is not unfrequent in the neighbourhood of faults. So general is this coincidence, that Professor Ramsay states that it is found, as a rule, that the greatest faults intersect strata which have been most disturbed. In cases where the derangement does not amount to contortion, the direction of the dip is often considerably altered on one or both sides of a fault. Contortions are sometimes seen where volcanic dykes have been intruded into fissures, and the direction of the foldings appear to have been influenced by their presence. They have also been formed in what, at the time of deposit, must have been soft and horizontal strata abutting against hard rock, it may be the sides of ancient valleys or of mountain ranges. Of the latter a well-known example occurs to the west of the Malvern range, where the Upper Silurian strata are greatly contorted, the cause of which was formerly attributed to what was considered to have been the subsequent protrusion of a boss of igneous granite, until the late Miss Phillips (sister to Professor Phillips) proved that a portion of the Upper Llandovery deposits, abutting against its sides, had been derived from the disintegration of this rock itself,* which Dr. Harvey B. Holl has since conclusively proved, so far from being of igneous origin, is itself a metamorphosed sedimentary deposit.†

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* British Association Reports, 1869 and 1871.

It is manifest that the presence of faults, of ancient valleys and ridges, and of volcanic dykes, have had a great influence in determining the direction and locality of contortions in strata; but it is evident, from what has been previously stated, that the same powers by which they have been produced have not been those which originated the contortions. But it will be better to defer the consideration of their origin until after discussing the facts and opinions which have been advanced respecting the cleavage of slate.

Some rocks have the property of splitting into laminæ independently of their original stratification, in a definite direction, extending often over wide areas, whilst the organisms they contain have become distorted, and the particles entering into their composition have had their position altered from that which they originally occupied. This quality has received the designation of "cleavage." Though limited in the British Isles to Palæozoic strata only, this property is not confined to any formation or geological era; "the Andes of Chili and Terra-del-Fuego contain clay-slate of Cretaceous age, and the black slates of Glarus, in Switzerland, which is formed with as true a slaty-cleavage as any in Wales, are of recent Tertiary age." Nor is there any reason to doubt that it is even now in process of formation where the conditions necessary for its production are present. It is best developed in clay-slate, such as is so much used for roofing purposes, but it is found, though not so perfect, in other stratified rocks, in beds of sandstone and limestone, even in those of volcanic ash, and more rarely in conglomerates and breccia. The coarser the materials which enter into the composition of the rock, so generally are the cleavage planes coarser and more irregular.

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* "Memoirs of the Geological Survey," vol. ii, p. 66.

† *Quarterly Journal* Geological Society, vol. xxi, p. 72.

Professor Sedgwick, in 1835,* was the first to systematically observe and describe the phenomena of slaty-cleavage, determining its distinction from jointed structure and from stratification; its formation being ascribed to chemical or electro-chemical action.

But Professor Phillips, in 1843,† from the character of the distortions which have taken place in the organisms contained in slate-rocks, regarded these changes as being due to mechanical causes.

The subject was followed up by Mr. D. Sharpe, in 1846,‡ and 1848.§ From observations with reference to the direction of the distortions of the fossils, and also from the fragments included in slate-rocks being flatter between, and parallel to the planes of cleavage, and longest along its dip, whereas when originally deposited they would have been lying on their flat sides in the beds, he determined that these alterations, and therefore cleavage, have been caused by pressure of the mass in a direction perpendicular to the cleavage, "under conditions of which we are ignorant."

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* "On the Structure of large Mineral Masses," &c.—Transactions Geological Society, vol. iii, p. 469.

† "On Certain Movements in the Parts of Stratified Rocks."—British Association Reports, 1843, p. 60.

‡ "On Slaty Cleavage."—*Quarterly Journal* Geological Society, vol. iii, p. 74. § Vol. v, p. 3.

Mr. Sorby, in 1853,* also demonstrated that the production of cleavage was the effect of lateral pressure, as shewn by the occasional crumpling of sandy beds interstratified with the slate; by the change of shape and dimensions of the green spots so frequently found in some slate-rocks; and by the positions and other changes which have occurred in waterworn flakes of mica as shewn by examination under the microscope. He also produced cleavage artificially by mixing flakes of oxide of iron, &c., with pipe clay, and subjecting the mass to pressure.

The occurrence of a structure in glaciers analogous to cleavage (and which may in fact be considered to form a true *ice-slate*), was observed by Professor Tyndall (1856);† this he determined had been induced under certain conditions by lateral pressure. He also caused perfect cleavage in wax, by subjecting it to pressure, and showed that it is constantly being produced in the process of rolling out iron boiler-plates, in the passage of a waggon over half dried mud, and in numerous other instances, when materials have been subjected to compression under similar conditions. The formation of puff-paste by the pastry cook is but "a grossly exaggerated case of slaty-cleavage."

Thus observation proves that changes in the dip of strata, contortions, and slaty-cleavage have been induced by lateral pressure, often propagated along lines extending in the same direction for distances of many, it may be hundreds of miles, and that in innumerable instances the same force has, at one and the same time, caused both contortion and that re-arrangement of the constituent particles of rock masses which has resulted in cleavage.

To what causes then may these phenomena, with any degree of probability be attributed? Not to alteration in the temperature of the earth's interior causing contraction, though this has been very frequently advanced as a possible cause of flexure and contortion; and the cleavage of slate was formerly ascribed to the action of heat. This will be evident if we compare the Upper Silurian strata of North Wales, where the beds are greatly disturbed by foldings, and cleavage is very general; with beds of the same formation in Shropshire and Staffordshire, where they generally lie either at a moderate angle or are nearly horizontal, cleavage is entirely absent, and the organisms embedded in them are in no wise distorted.

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* *Edinburgh New Philosophical Journal*, vol. lv.

† "Comparative View of the Cleavage of Crystals and Slate Rocks."—Appendix to "The Glaciers of the Alps."

Sir C. Lyell remarks that "the wide extent, in the United States of America and in parts of Russia, of Carboniferous, Devonian, and Silurian strata, which, although upraised above the sea, continue almost as level as when the beds were first thrown beneath its waters, clearly demonstrates the limitation of the agency, to which great contortions and foldings of stratified rock have been due, to very confined spaces in each epoch." As the effects have been localised, so also must be the cause; therefore, if contortions are due to contractions, caused by a diminution in the temperature of the earth, they must have affected the whole surface equally, and not have been confined to such very limited areas.

Sir Charles Lyell, in his address as President of the Geological Society, 1850, suggested a method by which, to a certain extent, flexures of strata will be produced. He asks "whether the subsidence of mountainous masses beneath the floor of the ocean, brought about by slow degrees, can possibly occur without causing beneath many of the sunk areas vast flexures of the strata, which, as they sink for miles vertically, must occasionally be forced to pack themselves into smaller spaces than those which they previously occupied." Depression must, as we have previously seen, necessarily cause compression of the subsiding portion until a certain depth is reached, but as it acts in every direction, the contortions must be irregular, unless there exists some cause which shall give them that definite direction which they so frequently assume. These flexures have often the same general tendency for many miles in length; thus the foldings of the strata of the Appalachian chain, having a breadth of fifty miles, take a N.N.E. and S.S.W. direction for nearly 1,500 miles, throughout which the Palæozoic strata have been so bent as to form a series of anticlinal and synclinal ridges and troughs. There must, therefore, have existed such conditions, extending constantly in the same direction, as shall have determined that of the lateral pressure which has induced such plications, and has in many instances caused cleavage in strata. The chief causes capable of producing these effects appear to be valleys and faults.

Valleys continue to follow the same direction, with some minor irregularities, for great distances, and their seaward extremities, as I think we have proved, necessarily subside, becoming gradually submerged and filled up with sedimentary matter, brought down by the rivers which traverse them. If this depression continues, compression to some extent must be induced, until a certain depth is reached, and the strata would become contorted and bent, so as to allow them to take up a less space than they formerly occupied; and the unconsolidated material, confined as it were between walls of hard rock, would have the direction of the pressure applied to it determined by that of the ancient submerged and filled-up valleys. Therefore, the ridges and hollows of the contortions would extend parallel to the course of the valley within whose area the strata have been deposited, the flexures being greater near the sides in consequence of the resistance which is afforded by the harder rock. If it is possible that contortions have in some cases been caused by lateral pressure acting in this manner, so also as slaty-cleavage is dependent on similar pressure, it is probable that it likewise would be induced under the same circumstances. To such an origin I would attribute the cleavage, as well as the contortions of the Wenlock rocks, at a distance of four miles to the north and the same to the south of Llangollen. These strata appear to be a deposit in a pre-Wenlock valley.

As Trappean dykes and other masses of intrusive rock so frequently occur without having caused disturbance of the strata they traverse, it is reasonable to conclude that, when contortions are present in connection with them, their formation has been influenced by the resistance which these consolidated masses afford to the pressure induced upon the occurrence of similar changes of level, and not to force applied at the period of these volcanic rocks passing upwards when in a state of fusion.

A more powerful agent in influencing the degree and direction of pressure, and consequently that of contortions of rocks, is the occurrence of faults, and it is generally recognized that their presence has an "intimate connexion with those foldings of strata which constitute anticlinal and synclinal axes," and that flexures extending in the same direction, for vast distances, have frequently been determined by the presence of faults. Combined with the foldings of the Appalachian chain, a fault implying a displacement of several thousand feet has been traced for eighty miles. The Great Craven Fault is a well-known and easily recognized example of a considerable displacement of the strata (2,000 feet), on the one side of which the beds of Carboniferous Limestone lie almost horizontally, whilst on the other the Millstone grit and the Coalmeasures, which have been thrown down against them, and the underlying Silurian rocks, dip at a considerable angle, and towards the fault, there also being an intermediate or secondary fault, in which the intervening beds of Limestone are bent in various directions at different localities. Though these faults have influenced the direction and degree of the contortions, their formation must be attributed to a different movement from that by which the faults have been produced.

We have seen that the wedge-shaped masses of rock, which, fractured from along the sides of fissures, have separated and fallen down, forming faults, have by so much enlarged the area they occupy, as the width of the included portion is increased from what was the original width at any point previous to the dislocation; also that there could be no difference, or very little, in the angle at which the strata lie in the depressed portion from that of the mass from which it has been fractured. But supposing the fault to have been formed during a period of upheaval, then, as the beds occupy a larger space horizontally than they did originally, upon depression taking place the strata must be compressed into a smaller compass, and be forced into foldings and contortions, their general direction lengthwise being the same as that of the faults. This same action would also originate cleavage, but this would not occur in any beds which have been elevated above the sea-level; as, in consequence of the drainage of the water they contain, such consolidation would take place that the movements amongst its constituent particles necessary to occasion it would be rendered impossible.

In faults which have occurred during periods of subsidence, and where deposition is in progress, not only would a portion of the lately-deposited sediment included between the sides from which the dislocated portion has been fractured, but also the hollow formed by its depression would naturally be filled up by the continual accession of fresh materials; therefore upon upheaval the portion contained between these walls must be compressed, and contortions, extending lengthwise in the direction of the line of fault would occur; and, as those strata have not become consolidated, the pressure thus induced would cause a re-arrangement of the constituent particles, as well as a flattening of any semi-solidified deposit, and thus induce that tendency which slate-rocks possess of splitting at an angle greater or less to that of the line of stratification.

This method of accounting for the contortion and cleavage of rocks, by attributing the phenomena to the influence which faults would occasion in a subsequent alteration, whether it be by elevation or by depression of the surface, was advanced by me during 1870, in reference to the great disturbance which has taken place in the Lower Silurian rocks in the neighbourhood of Llanfyllin;* but I subsequently discovered that I had been anticipated in the suggestion, so far as it relates to contortions of strata, by the late Professor Jukes, who used a similar argument respecting the formation of certain contortions he had observed in the thick coal of South Staffordshire in connexion with faults, and estimated the possibility of vast anticlinal and synclinal curves having originated in the same way as the minor cracks and squeezes in the case referred to;† though in the next paragraph he appears to doubt this influence of faults in the production of contortions. But Jukes was not the original propounder of this theory. Professor Phillips, in the "Memoirs of the Geological Survey," describing the geology of the Malvern Hills, had previously arrived at similar results from similar reasoning.*

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* Proceedings of the Liverpool Geological Society, Session 1870–71, p. 30.

† "Student's Manual of Geology," chap. xiii.

In some rocks, and we can hardly find better examples than in the Trias of our own neighbourhood, changes in the direction of the dip of the strata are frequently evident on each side of a fault, the general direction of the strike of the bedding being the same as that of the lines of the larger faults. The reasoning we applied respecting contortions will likewise account for their production; they may even be considered to be, to a certain extent, flexures which have not progressed sufficiently to be considered contortions. Nor are we without evidence of that lateral pressure which might produce these changes. This is evident from the frequent occurrence of oblique and occasionally of horizontal slickensides; and from the "fault-rock," which the faults running north and south, contain, instead of lying horizontally as when first deposited, having been converted into slabs taking a direction parallel to the hade of the faults. I would myself compare this lamination to a coarse kind of cleavage, and as being upon a limited scale analogous to that of slate.

In the two addresses which I have now had the honour of delivering to you, it has been my endeavour to prove the strict interdependence which exists between different geological phenomena. Change cannot take place in one direction without causing alteration in another. Prolonged and almost imperceptible are the actions that have produced the immense amount of denudation that has taken place upon the earth's surface; fully as slow has been the redeposit in other localities of the debris resulting from that denudation. The most enormous contortions, and the most abrupt bendings of strata, as well as that change in the position of the constituent particles by which slaty-cleavage has been induced, have occurred in the most gradual manner. They have been effected with great power, it is true, but without violence. I believe the time must shortly arrive when it will be generally accepted by geologists that "the most gigantic curvatures of strata have been the result of intense pressure, so moderated in its application as to have been just sufficient to overcome the resistance opposed to it, and that this motion has been as insensible as the unfolding of the petals of a flower."* Even the volcano and the earthquake must be removed from the category of cataclysms and convulsions. With more probability may they be considered as the necessary result of those slow and imperceptible changes, by whose accumulated power certain physical alterations have been made in the earth's crust. In conclusion, I must express my conviction that a careful examination of the phenomena we have been considering, will demonstrate the prime mover which has produced them to be denundation, with its consequent deposition, acting and reacting on the crust of the earth equally balanced on its fluid interior.

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* Vol. ii, p. 142.

NOVEMBER 12TH, 1872.

THE PRESIDENT, ISAAC ROBERTS, F.G.S.,
in the Chair.

WILLIAM SHONE, JUN., and JOHN GRIFFITHS were elected Ordinary Members of the Society.

The following communications were read :—

NOTES ON THE SUB-WEALDON EXPLORATION.

BY ISAAC ROBERTS, F.G.S.

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* Sir C. Lyell, Presidential Address, 1850, *Quarterly Journal* Geological Society, vol vi, p. 83.

GLACIAL STRIÆ AT MILLER'S BRIDGE, BOOTLE, NEAR LIVERPOOL.

BY T. MELLARD READE, C.E., F.G.S,

THESE striations were discovered by the author on the rock at the back of the Turnpike, in Stanley Road. They consisted of rudely parallel gougings, from N.E. by E. to E.N.E., on a boss of rock with cross striations 22° W. of N. Similar gougings E.N.E., as well marked as the flutings of a column, were disclosed on removing the sand which covered a jutting piece of rock a little distance off. The edge of the rock above the excavated face, along Stanley Road, also exhibited the scorings, and on a flat table of rock in the vicinity other striæ were plainly seen cut clean and straight as with a diamond. In this case the N.N.W. striations were the most prominent; the E.N.E., though quite distinct, being fewer in number and less prominent.

These are the only recorded examples of cross striations found near Liverpool. It was pointed out that if the E.N.E. lines were continued, they would about intersect Snowdon, and if those N.N.W. were continued, they would intersect St. Bee's Head or pass a little to the west of Scawfell.

The E.N.E. gougings, from the rounded nature of the edge of the rock, appeared as if ground down by a force acting from the westward. The author advocated the hypothesis of an ice-sheet moving from the Lake District, as suggested by Mr. Tiddeman,* to account for the N.N.W. striations, and assumed the existence of a force or ice-sheet generated on, and acting from the Snowdon range to account for those E N.E. The mountains of Wales, as well as those of Cumberland, must have been at one and the same time centres of dispersion, and the variations of force consequent upon the increase or diminution of snow on either, would account for the variations in the direction of the striations found in different localites about Liverpool. In this case the resultant of the two pressures, commencing probably N.N.W., finished off E.N.E., or at right angles to its original direction.

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* "Evidence of the Ice Sheet in North Lancashire."—*Quarterly Journal* of Geological Society, June 19th, 1872.

DECEMBER 17TH, 1872.

THE PRESIDENT, ISAAC ROBERTS, F.G.S.,
in the Chair.

WILLIAM KING, Sc.D., and Professor of Mineralogy and Geology in Queen's College, Galway, was elected an Honorary Member of the Society.

WILLIAM SEMMONS and MICHAEL FITZPATRICK were elected Ordinary Members of the Society.

The following communications were read:—

SECTION OF STRATA ABOVE THE BOULDER-CLAY AT WHITECHAPEL, LIVERPOOL.

BY ISAAC ROBERTS, F.G.S.

IN excavating for the foundations of the premises for the Midland Railway Co., on the west side of Whitechapel, and south side of Crosshall Street, the following section of the ground above the Boulder Clay was observed. The depths are given from the level of the curbstone in Whitechapel.

a. 8½ feet of building *debris* and rubbish filled in to raise the surface to the present level.

b. 1½ feet of vegetable and sand soil, being the surface of the land before it was built upon, many roots of shrubs found in this bed.

c. 4 to 5 feet of Blue Clay, intermixed with trunks of trees and vegetable matter, which had probably drifted. In this bed were found a part of the *tibia* of a deer and a *femur* of a goat or antelope, also a bronze coin about the size of a penny piece, all trace of any inscription being obliterated by oxidation.

d. 3 to 4 feet of peat, with the stems and roots of trees penetrating in several directions. No doubt can be entertained that this bed is *in situ*. A piece of oak, which had been charred by fire, and seven hazel nuts in a cluster (three whole and four broken) were found about the middle of the bed. This bed, and the one marked *c.* above, thin out and form one bed within a short distance.

e. Six inches of coarse sand with a few roots penetrating.

f. 2 feet of blue coarse sand with subangular pebbles and boulders. No roots in this bed.

g. Boulder Clay. The surface being twenty feet below Whitechapel, or eight feet below the Old Dock Sill, and the beds above described lay in a hollow or small valley in the Boulder Clay, which valley had a direction north and south.

The deepest part of the hollow is about thirty feet to the westward of Whitechapel. On referring to a copy made of Leland's map of Liverpool, dated 1539, we find that the pool extended from the River Mersey for some distance along, and to the north of where Whitechapel now is, and that a sluice existed, I suppose to prevent the tides from overflowing the low land in this locality. The existence of such a sluice would enable us to account for the presence of the lower of the vegetable beds referred to above, which is only eleven feet above the level of the Old Dock Sill, without having recourse to the theory of a subsidence of the land since the vegetation grew.

CALAMITES AND THEIR ALLIANCES.

By Frederick P. Marrat.

Order II.

A CALMITEÆ, *Brongt.*

Calamites Suckowii, *Brongt.*
var. undulatus, *Sternb.*
var. ramosus, *Brongt.*
Branches and foliage, Asterophyllites foliosus, *Lindl.*

Calamites dubius, *Artis.*, tab. 13, *Brongt.*, tab. 18, f. 1—3.

Calamites approximatus, *Scloth*, *Brongt.*, tab. 15, f. 7, 8. *Lindl.* and *Hutt.*, tab. 77.

A very fine series of specimens, exhibiting a large amount of variation.

Calamities cannæformis, *Scloth*, tab. 21. *Lindl.* and *Hutt.*, tab. 78, 79.
var. decoratus, *Brongt.*, tab. 14, f. 1—5.
var. nodosus, *Lindl.* and *Hutt.*, with its branches and leaves.
var. steinhaueri; *Brongt.*, tab. 18, f. 4.

SPECIES DUBIÆ.

Calamites Lindleyi., *Sternb.*, mougeotii, *Lindl.* and *Hutt.*, tab. 22.

B. RAMI ET RAMULI FOLIOSI.

CALAMOCLADIUS, *Sch.*

CALAMOCLADIUS, (Calamites) LONIFOLIUS, *Brongt.*

ASTEROPHYLLITES, *Brongt.*, *Lindl.* and *Hutt.*, tab. 18.

AST. COMOSO and JUBATA, *Lindl.* and *Hutt.*, tab. 108—133.

CAL. RIGIDUS, *Geinitz.*

ASTEROPHYLLITES RIGIDA, *Brongt*, Brad. p. 159, *Lindl.* and *Hutt.*, vol. 3, tab. 211.

CAL. EQUISETIFORMIS, *Scloth.*

ASTEROPHYLLITES EQUISETIFORMIS, *Brongt*, Prod. p. 159, *Lindl.* and *Hutt.*, tab. 191.

CALAMOCLADIUS (Calamites) GRANDIS, *Stern.*, *Lindl.* and *Hutt.*, tab. 19. A portion of the stem.

CALAMITES NODOSUS, *Lindl.* and *Hutt.*, tab. 15 and 16.

CALAMOCLADIUS (Calamites), FOLIOSUS, *Lindl.* and *Hutt.*, tab. 25.

ASTEROPHYLLITES.

CALAMOCLADIUS (Calamites), TENUIS, *Marrat.* Figured in the Proceedings of the Liverpool Naturalists' Field Club for 1870-1.

BORNIA, *F. A. Roem.*

BORNIA RADIATA, *Brongt*, tab. 26, f. 1, 2.

SPHENOPHYLLUM, *Brongt.*

Prod. d. une hist. d veget foss.

SPHENOPHYLLUM EMARGINATUM, *Brongt*, class des. veget foss.

SCHLOTHEIMII, *Lindl.* and *Hutt.*, tab. 27.

SPHENOPHYLLUM EROSUM, *Lindl.* and *Hutt.*, tab. 13.

var. B. SAXIFRAGÆFOLIUM, *Schimp.*, tab. 25, f. 10—14

ANNULARIA, *Brongt.*

Annularia longifolia, *Brongt.*

Asterophyllites equisetiformis, *Lindl.* and *Hutt.*, tab. 124. *Schimp*, tab. 26, f. 2.

var. tuberculata, *Lindl.* and *Hutt.*, tab. 14. (fruit);

Annularia radiata, *Brongt.*

Asterophyllites galioides, *Lindl.* *Hutt.*, tab. 25, f. 2.

Annularia.

Asterophyllites acicularis, *Dawson.* *Quarterly Journal* Geological Society, tab. 13, f. 16.

Annularia Dawsonii, *Sch.*

latifolia, *Dawson.* *Quarterly Journal* Geological Society, vol. 18, pl. 13, f. 17.

JANUARY 14th, 1873.

The President, ISAAC ROBERTS, F.G.S.,
In the Chair.

John E. Pearson, Thomas Ward, and John Dodd were elected Ordinary Members of the Society.

The following communications were read:—

THE GRAPTOLITES OF THE ARENIG ROCKS OF ST. DAVID'S, SOUTH WALES.*

By John Hopkinson, F.G.S., F.R.M.S.

The lowest beds of the Silurian rocks in the immediate vicinity of St. David's consist of a series of black iron-stained shales, about 1000 feet in thickness, which, from their stratigraphical position and from the evidence afforded by their fossils, have been inferred to be of Arenig age. They were first noticed by Messrs. Salter and Hicks, in a report furnished to the British Association at the Nottingham Meeting, in 1866, and have since been more fully described by the latter in a paper read before the Liverpool Geological Society in 1869.

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* Read before the Geological Section of the British Association at Brighton, August 16th, 1872.

The recent discovery in these beds of a considerable number of characteristic Arenig Graptolites has confirmed the previous conclusion as to their age, and furnished conclusive evidence of their equivalency with the Quebec group of Canada, the Skiddaw slates of Cumberland, and the Arenig group of Shelve.

The graptolites were collected by Messrs. Hicks, Homfray, Lightbody, Kirshaw, and myself, in the course of a few days we spent together at St. David's, in July. The localities from which we obtained them are Ramsey Island and Whitesand Bay. Nearly all are from the lower beds of the series. Although a few species are known to have a considerable range, the majority seem to be very local and confined chiefly to thin zones. These, together with other forms, may possibly be found in the higher beds which have not been so thorougly worked.

Of the true graptolites, or RHABDOPHORA, the only genera of undoubted occurrence are *Didymograptus*, *Tetragraptus*, and *Phyllograptus*. *Didymograptus* is represented by five species, three of which—*D. extensus*, Hall; *D. patulus*, Hall; and *D. pennatulus*, Hall, are characteristic of the Quebec group and the Skiddaw slates; *D. patulus* also occurring in the Arenig rocks at Shelve. The other species are new. Of *Tetragraptus* but one species, *T. serra*, Brong., a Quebec and Skiddaw form, has been found. *Phyllograptus* also is only represented by a single species, which is new. There is also another new species—a very peculiar branching form, which I have referred provisionally to *Loganograptus*.

The absence of any specimens undoubtedly referable to *Dichograptus* is remarkable, as this is a common Quebec genus. *Diplograptus* and *Climacograptus*, genera of very rare occurrence in the Quebec group, have not as yet been found here. They are more characteristic of Llandeilo than of Arenig rocks, and probably did not appear until some time after the commencement of the Arenig period. If so they are most likely to be found in the higher beds of the series at St. David's.

Of the allied forms, all the genera of the so-called "dendroid" graptolites, so characteristic of the Quebec group, are present in the St. David's beds. *Ptilograptus* is represented by two new species, and *Dendrograptus* by five species, three of which—*D. divergens*, Hall; *D. flexuosus*, Hall; and *D. striatus*, Hall, are at present only known to occur elsewhere in the Quebec group, the other two being new. One of these, however, was found in these rocks some time since by Messrs. Salter and Hicks, and has received the M.S. name of *D. arbuscula*. *Callograptus* is also represented by five species, three—*C. elegans*, Hall; *C. (?) diffusus*, Hall; and *C. Salteri*, Hall, being Quebec forms and two being new, and lastly, of *Dictyonema* but one species, which is new, has been found.

Many obscure impressions which I have referred to the genus *Retiolites* also occur. One species seems to agree perfectly, as far as its state of preservation allows of comparison with Professor Hall's figures, with his *R. ensiformis* of the Quebec group. Another appears to be distinct from any species yet figured.

In this varied graptolite fauna the most important discovery is that of a *Callograptus* with an entire "hydrocaulus" or main stem, and a "hydrorhiza," the organ of attachment. This hydrorhiza appears as a series of interlacing or anastomosing fibres at the proximal end of the main stem, which suddenly widens out, and becomes more loose or fibrous in structure as it merges into the adhesive fibres. From its presence in this specimen it may be inferred to be an essential organ of the genus *Callograptus*, which is thus proved to have been capable of attachment to foreign bodies. Its rarity may be accounted for by its perishable nature, and the probability of the graptolite being almost invariably severed from the substance to which it was attached at the junction of the hydrocaulus with its hydrorhiza. The other dendroid graptolites were also most probably fixed forms. "The stems of *Dendrograptus*," Professor Hall says, "are enlarged towards their base, and sometimes present a sudden expansion or bulb, which I have inferred may be the base or root, once attached to another substance, or imbedded in the mud or sand of the sea-bottom." These dendroid graptolites are so nearly allied to each other (*Callograptus* forming an intermediate link between *Dictyonema* and *Dendrograptus*, to which also *Ptilograptus* is nearly allied,) that we may safely infer that they all had a similar mode of existence. *Ptilograptus* and *Dendrograptus* are thus, in their mode of growth, as well as in their general form, and, as far as the imperfect state of preservation in which they usually occur enables us to determine, in their intimate structure also, essentially similar to our recent Sertularian Hydroida; while *Callograptus* and *Dictyonema* differ only in their branches being more or less regularly connected together by transverse processes.

The graptolites and their allies are now thus known to be represented in the Arenig rocks of St. David's by nine genera and about twenty-two species. Of the true graptolites three genera, namely, *Tetragraptus*, *Loganograptus*, and *Phyllograptus*, are exclusively confined to the horizon of the Quebec and Skiddaw groups. They have not yet been found in the Arenig rocks of Shropshire. The remaining genus, *Didymograptus*, is by far the most abundant in the Arenig group, occurring in rocks of this age in Canada, Cumberland, and Shropshire. In higher rocks it is represented by but two species — *D. Murchisoni* and *D. serratulus*. The former is found in the Lower Llandeilo, at Abereiddy Bay, near St. David's, and at Builth, and the latter in the Hudson River group (Caradoc?) of New York. It has also been recorded by Professor Nicholson from the Skiddaw slates of Cumberland.

The four genera of dendroid graptolites have a more extensive range, one of them, namely, *Dictyonema*, lasting from the Cambrian to the Devonian period; but they have only hitherto been found together, and in any abundance, in the Quebec group of Canada. They occur, however, in the Arenig rocks of Shropshire. During the recent visit of the Geologists' Association of London to Ludlow and the Longmynds, Mr. Lightbody pointed out to me, in the Ludlow Museum, a few graptolites which he had collected at Shelve, amongst which were some dendroid forms similar to what we had just been collecting at St. David's. A day was afterwards devoted by the Association to the neighbourhood of Shelve,* and here, amongst other fossils collected were a few graptolites, the only dendroid form being a single specimen of *Callograptus*. A few days afterwards, accompanied by Mr. W. D. La Touche, I again visited the locality, and we then found, in the lower part of the Arenig rocks, underlying the great mass of the Llandeilo, a graptolite zone, in which the genera *Ptilograptus, Dendrograptus, Callograptus*, and *Dictyo-*

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* For a valuable Paper on "The Geology of the Country Around Shelve," by G. H. Morton, F.G.S., see Proc. Liverpool Geol. Soc., vol. I. An interesting account of "A Ramble in West Shropshire" by the Rev. J. D. La Touche, M.A., in the *Intellectual Observer*, vol. XI, April and June, 1867, should also be referred to.

nema,* are represented by species, some of which are identical with, and others nearly allied to, those in the St. David's beds, and in the Quebec group of Canada. These beds are therefore (assuming that the Arenig group admits of division into an upper and a lower series) of Lower Arenig age. As these fossils are from the lower beds of the series at St. David's, the entire Arenig group is most probably here represented.

The highest beds of the Arenig group are succeeded, in the neighbourhood of St. David's, by the Lower and Upper Llandeilo, and these again are followed by beds of Bala age. The sequence of these Lower Silurian rocks in the vicinity of St. David's is therefore entire.

The Cambrian rocks, also, are here more fully represented than in any locality in Britain, a complete section, from the Longmynd group, through the Menevian beds and Lingulella flags to the Tremadoc rocks, being here exposed.

Nowhere, in fact, have we such a complete and unbroken succession of the Cambrian and lowest Silurian rocks as is exhibited in the fine coast section of the St. David's promontory, which has alone furnished, almost entirely through the researches of Mr. Hicks, the key to the succession of these Older Palæozoic rocks.

The following is a list of the Graptolites and allied fossils now known to occur in the Arenig rocks of St. David's.

Didymograptus extensus, Hall, sp.
D. *patulus*, Hall, sp.
D. *pennatulus*, Hall, sp.
D. *plumula*, sp. nov.

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*A Dictyonema has already been recorded from Shelve; see Mr. Morton's paper mentioned above.

D. *sparsus*, sp. nov.
Tetragraptus serra, Brongniart, sp.
Loganograptus (?) implicatus, sp. nov.
Phyllograptus stella, sp. nov.
Retiolites ensiformis (?), Hall.
Ptilograptus cristula, sp. nov.
Pt. *Hicksii*, sp. nov.
Dendrograptus arbuscula, Salter, M.S.
D. *divergens*, Hall.
D. *flexuosus*, Hall.
D. *pumilus*, sp. nov.
D. *striatus*, Hall.
Callograptus (?) diffusus, Hall.
C. *elegans*, Hall
C. *radiatus*, sp. nov.
C. *radicans*, sp. nov.
C. *Salteri*, Hall.
Dictyonema cancellata, sp. nov.

THE BURIED VALLEY OF THE MERSEY.

By T. Mellard Reade, C.E., F.G.S.

Some two years ago, when prosecuting my Post-glacial researches, I happened to get supplied with a few records of well-sinkings and borings in the upper reaches of the river. Though not immediately bearing upon the subject of my investigations, they irresistibly led to speculations upon the Pre-glacial form of the Mersey Valley. Of late, being engaged on the subject of the drift and of ice action, and having in the meantime accumulated more data upon which to work, I have thrown my thoughts

together in a form that I trust may prove a step towards the elucidation of the interesting phenomena I am about to call your attention to.

Present Bed of the River.—Before considering the probable form of the rocky bed previously to the laying down of the Drift, or Boulder-clay series, which, however, is not necessarily the Pre-glacial form, it will be advisable to take a glance at the conditions that now obtain and the dependency of the form of the present bed of the river on tidal influences, within its estuary, together with the fresh water flow both above and below Runcorn Gap.

The form of the Mersey and its estuary between its embouchere and Warrington, is so well known to you all that it will need little description. It may be roughly described as forming a parabolic curve to the south, between Birkenhead and Warrington. From Birkenhead it flows northwards in an approximately N.N.W. direction, the sea channel getting gradually more deflected to the westward as it approaches Formby Point. At New Brighton its width, before the docks were formed, was 8,000 feet; at Prince's Basin it narrows to 3,000, gradually expanding to 16,000 feet at Ellesmere Port, situated near the vertex of the curve; it then narrows again to 4,000 feet at Weston Point, and sustains this width until it suddenly closes in at Runcorn Gap—a rocky gorge, 1,400 feet wide at high water level; it then expands again to 4,000 opposite the east end of Runcorn, contracting again to 600 feet at Fiddler's Ferry, and to 150 feet at Warrington Bridge. The tidal area between the Rock Lighthouse and Warrington Bridge is 22,450 acres. The vertex of the curve between the mouth of the Weaver and Ince is occupied by a large area of marsh land, consisting of the Frodsham and Ince Marshes and the Stanlow Marshes at Ellesmere Port. Were it not for these Post-glacial deposits, before described by me,* and the marsh land at Widnes and along the banks of the river up to Warrington, the tidal area would be increased considerably. In the "Report and Memoir of the Survey of the River Mersey, 1860-61," the authors (Messrs. Parks and Hills), estimate the high-water line between the Rock Lighthouse and Warrington Bridge at 74¼ statute miles—33.35 on the Lancashire and 40.9 on the Cheshire shore. The following schedule shows the nature of the river margin, and is extracted from the same report, which is well worthy of attentive study:—

SCHEDULE.

		Distinctive Features of High-water Boundary.	Extent in Miles to Nearest Decimal.		Total Extents.
			Lancashire.	Cheshire.	
Artificial.	1	Wall	12.0	10.0	22.0
	2	Embankments, Rubble faced	0.75	5.4	6.15
	3	Embankments, Earth or Sod	8.8	13.0	21.8
					49.95
Natural.	4	Cliffs of Sandstone Rock	0.4	3.4	3.8
	5	Cliffs of Clay	7.6	4.6	12.2
	6	Low Shelving Shore	3.8	4.5	8.3
			33.35	40.9	24.3

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* "Post-glacial Geology of Lancashire and Cheshire."—Proceedings of Liverpool Geological Society, Session 1871-72.

Of the natural shore an extent of 12 miles consists of clay cliffs, varying in height from 5 to 40 feet, and the "established" or permanent tidal limit is estimated at 54 miles. Of the wasting action of the tide on the unestablished portion of the shore, estimates are given; but for this, and other information of a similar character, I must refer you to the report itself.

Having now given you a general description of the character of the river area and margins, I must ask your attention to the section (fig. 1) of the river from Formby Point to Warrington Bridge, which I have enlarged from the one prepared by G. F. Lyster, Esq., M.I.C.E., and given in "Beardmore's Manual of Hydrology." The red line represents ordnance datum, or mean half-tide level, the blue, high water of a 19-feet tide, and the strong black line the average form of the river bed. Without going into minute calculations of areas, it will be observed that the depth of the estuary of the river is in an inverse ratio of its width, excepting in that portion between the Rock Lighthouse and Wallasey Pool, where the average of the depths varies but little, and above Ellesmere Port to Runcorn Gap, where a regular gradient obtains, due, doubtless, to the regular flow of the fresh water of the river, here not so long subject to tidal influences. A sudden rise in the gradient occurs at Runcorn; and from thence the gradient as far as Warrington Bridge is about the same as that below Runcorn. It may be observed that, were the section drawn from deepest point to deepest point at intervals, the bottom would show a very irregular line, which may be seen on figure 2 of Messrs. Parks and Hill's report, which also exhibits the bed of the river as it was in 1819-22, according to the survey by F. Giles, C.E. In considering the nature of the bottom I shall have occasion to refer to this section again.

Having now, with sufficient minuteness for the purpose, described present conditions, we will proceed to ascertain if anything can with certainty be predicated of the form of its rocky bed immediately after its desertion by the ice-sheet, which, without doubt, filled it previously to the deposition of the Northern Drift. With this object in view, we will commence an examination of what data I have been able to gather together, proceeding from Warrington towards the river mouth; premising by the consideration that such data must be necessarily of an imperfect nature from the intervals between the borings, but, for all that, perhaps enabling us to arrive at probable general conclusions.

Through the kindness of my friend, Mr. Robt. Vawser, Borough Engineer of Warrington, I have been supplied with borings and sinkings of wells in the neighbourhood of Warrington, showing the surface levels and the level of the rock at the several points marked on the map:—

	39.00 surface.
Dallam Forge, A—	6.00 rock.
	——
	40.0 S
White Cross, B—	4.0 R
	——
Manchester Road, C—	33.0 S
	13.0 R
	——

Note.—The lines represent ordnance datum, and as the figures occur above or below, the levels are above or below that datum.

D—Rock, 16 feet below surface, level not known, but between the 25 and 50-feet contours.

E—Buried forest at 15 feet below surface.

Messrs. Roberts, Dale, and Co.'s Works, 200 yards east of Warrington Bridge:—

F (figs. 1 & 4)— $\frac{22.00\text{ s}}{65.50\text{ R}}$

Sankey Whitelead Co.'s Works, Sankey Bridges:—

G (figs. 1 & 4)— $\frac{20.00\text{ s}}{80.00\text{ finished in gravel.*}}$

The two last bores are evidently in the old river bed, though not necessarily in the deepest part. The strata penetrated are as follows, the two upper members being in both cases probably Post-glacial, the remainder true drift:—

F	Ft. in.
Soil	4.3
Sand	8.0
Clay	5.0
Quicksand	40.0
Clay	20.8
White Rock (probably a boulder.)	5.0
Clay	4.6
Total	87.5

This boring is probably at or near the confluence of the old Sankey Brook with the Mersey.

G	Ft. in.
Soil	1.6
Sand	6.6
Boulder-clay	45.0
Sandy Gravel	2.0
Boulder-clay	25.0
Sand, mixed with Coal Dust	5.0
Clay, with bands of Gravel	15.0
Total	100.0

Left off in about 3 feet of coarse gravel, much water-worn; depth to rock unknown.

Bore-hole F shews the rock at Warrington Bridge to be about on a level with the *present bed of the river opposite Wallasey Pool,* while bore G shows that at Sankey

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* The two last borings only are shown on the appended map.

Bridges the rock is not less than 15 feet below it, and may be more. About one mile higher up Sankey Brook, the rocky valley of that tributary is only a few feet below ordnance datum, covered by a bed of gravel and by Post-glacial deposits.* What the width of the Mersey rock-valley is at Warrington I have no means of ascertaining; but the alluvial flats are about one mile wide at Sankey Bridges, and this is some indication, though there may be a deep channel at the point of borings; on the other hand the deepest part of the old bed may possibly be nearer the centre of the present valley.

The strata penetrated by bore-holes A, B, and C, consist of alternations of clay, marl, blue clay, dry sand, quicksands, and gravels—all, apparently, members of the Drift. At the Warrington Gas Works the rock is 20 feet below the surface, and is covered with shingle and boulders, stratified sand, and gravel beds; but as my object is not specially with the Drift, I must leave the further consideration of these glacial beds till another time.

This information, fragmentary and imperfect as it is, is still quite sufficient to establish the existence of a deep rock valley running close to the south side of Warrington, and within the limits of the present valley, with branches from tributaries such as the Sankey Brook. We have not, however, sufficient data to pronounce positively whether the sides of the valley are of a gradual curve in vertical section, or whether cliffs exist at any point; but I should not be surprised to ascertain that, though the general contours are rounded, cliffs may exist such as we see at the natural amphitheatre at Bromboro' Pool—formerly filled with, but now denuded of, Boulder-clay. Though, of course, the possibility of these latter cliffs being Post-glacial must not be lost sight of.

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* "Post-glacial Geology of Lancashire and Cheshire." section 22, plate 4.

Widnes.—Proceeding down the river, the next locality at which I have been enabled to collect information is Widnes. Through the kindness of Mr. Ebenezer Timmins, engineer and contractor, of Runcorn, I am in possession of the most complete set of borings in one locality it has ever been my good fortune to possess, and, in addition to this, they have proved of the utmost importance in settling a most interesting point in the enquiry. The position of the wells are marked on the 6-inch ordnance sheet, and their depth is shown in the section. The method adopted in placing the wells in the section is to project them on to it at right angles to the central or sectional line. Thus two wells, apparently almost in contact, may be separated by an actual distance of a mile. It is necessary to allude to this to prevent misconception.

Having borings above and below Runcorn Gap, showing the rocky bed considerably below that shown in the section 25, plate 4, of my "Post-glacial Geology of Lancashire and Cheshire," my mind was much exercised to discover whether the upper valley above Runcorn formed a separate lake basin, or whether the section was incorrect and there existed a deeper gully, such as I will presently explain. With this object, I wrote to Mr. W. Baker, C.E., the engineer of the bridge, who originally supplied me with the section, to ascertain if the rock had been proved. He informed me it had not been proved, but, on consulting Mr. Timmins, it was his opinion that the rock had been proved all through the gap by the screw piles driven into the bed to support the staging upon which the girders were built *in situ*. He decidedly thought that they never could have been trusted unless hard down on the rock. This, I am inclined to think, is the true state of the case; but, whether absolutely correct or not, the borings you see marked on the plans prove conclusively that the

Pre-glacial river did not run through Runcorn Gap. This discovery is most important, as the formation of the upper valley of the Mersey was most difficult to account for otherwise than by the actual scooping out of the bed by ice moving transversely to the river; but that is an unsatisfactory hypothesis, as, short of an outlet, it does not account for the valley at Warrington and its branching streamlets.

The levels of the surface and of the rock, as shown by these borings, are as follows:—

Martin Taylor's Works:—No. 1. (fig. 5)— (bore in progress, rock not reached)—	20.00 s	110.00 R
N. Mathieson and Co.:—No. 2 (fig. 5)— (approaching the rock)—	20.00 s	89.00 R
West Bank Metal Works:—No. 3 (fig. 5)—	20.00 s	92.00 R
Gaskell, Deacon, & Co.'s Works:—No. 4 (fig. 5)—	20.00 s	115.00 R
Lambert's Copper Works:—No. 5 (figs. 5 & 1)—	22.00 s	141.00 R
Tharsus Sulphur & Copper Works:—No. 6 (fig. 5)	25.00 s	75.00 R
Wells and Galloway, Lugsdale Chemical Works:— No. 7 (fig. 5)	25.00 s	43.00 R

27.00 s
Sullivan & Co., British Alkali Works:— ——
No. 8 (fig. 5)—93.00 R

22.00 s
William Gossage & Sons, Widnes Soapery:— ——
No. 9 (fig. 5)— 10.00 R

15.00 s
Ditton Brook Iron Works:—No. 10 (fig. 5)— ——
35.00 R

At the boat-house the rock comes to the surface. The north side of Runcorn Gap is thus proved to be a boss of rock, and this is well shown in the section of Runcorn Bridge before referred to; but I must correct one error. What is there put down as Red marl of the Trias I have satisfied myself is Boulder-clay, though some of it is almost undistinguishable from the Red marl.

A reference to the section will show how very much the rock in the deepest borings at Widnes lies below the bed of the river at Wallasey Pool—the deepest (No. 5) being no less than 76 feet lower. It will also be observed that the form of the bottom will be that of a pretty steep gorge. Between wells No. 7 and 9, about 1,000 feet apart, there is a fall of 97 feet, or nearly 1 in 10; between 7 and 6, 800 feet apart, 32 feet; and between 6 and 5, 750 feet apart, 65 feet. Bore No. 4 is evidently not in the deepest part of gorge, though near it. Bore No. 1 is apparently *at the junction of the valley drained by Ditton Brook* and the Mersey, as the rock rises to the westward, and at Ditton Brook Ironworks it is only 35 feet below ordnance datum. I have marked in the 1-inch scale map the supposed former course of the river, and I have drawn an approximate contour in dotted line on the 6-inch map, from which it will be seen what I imagine the sectional form to be like. Where the new Liverpool Extension Railway passes through Farnworth, the rock is covered with about 16 feet of Drift, and is about 109 feet above ordnance datum. On the Cheshire side the rock rises rapidly, and is covered by about 18 feet of Boulder-clay in the Runcorn streets.

The nature of the deposits penetrated is shown in the section of No. 5—Lambert's Copper Works—which Mr. Timmins has kindly allowed me to copy. They are as follows:—

No. 5.

Cinders	6.0
Soil..	1.0
Clay	8.0
Quicksand	12.6
Strong Clay	19.6
Quicksand	15.6
Strong Clay	95.9
Sand and Gravel	5.0
Total	163.3 rock.

I did not see the boring of No. 5 when in progress; but No. 2, not yet completed, I did see, and procured specimens which I now submit to you. The record is as follows:—

No. 2.

1. Marsh Clay	7.0
2. Quicksand	23.0
3. Brown Clay	10.0
4. Quicksand	6.0
5. Boulder-clay	44.0
Total	90.0

The two first members are Post-glacial. 3 is brick clay; but the bulk of the clay of 5 was of a very fine smooth nature, very free from sand and stones, and, I believe, has been derived from the Keuper marl. When I examined the boring, they had reached 109 feet, and were in a clay very much mixed with red sand; and in this sand Mr. Timmins informs me he usually finds many waterworn pebbles. The pebbles I exhibit I obtained from well No. 4; they lay on the rock mixed with red sand.

Mr. Timmins also informs me that they usually meet with more stones in the lower clay, and of increasing size. I also show specimens from bottom of another bore-hole —one being a glaciated piece of mountain limestone, the others apparently millstone grit. Mr. Williams, C.E., formerly Surveyor to the Weaver Navigation, tells me that at Weston Point, in constructing the Canal Lock, he came upon a great number of boulders lying on the rock. I wish to call your special attention to the fact of a bed of pebbles usually lying upon the rocky bottom, as it will form an element in my conclusions; and also to the prevalence of red sand, due to the grinding or attrition of the Triassic rocks. At the Tharsus Works (No. 6) there was 10 feet of red sand or rotten rock. I shall refer to this again when I come to my arguments.

Hooton.—The section of this well (H, fig. 4) was exhibited to the Society by Mr. Robert Bostock two sessions ago, and he has kindly supplied me with a copy. It penetrates 169 feet of Drift; the rock was reached at about 65 feet below ordnance datum, and it is in every way a remarkable boring. The lower members consist mostly of gravel and sand. It is situated about two miles from the margin of the Mersey, and is noted here principally on account of its being in a branching valley of the Mersey, having its present outlet in Bromboro' Pool. The rock is about level with the lowest point of the present bed of the Mersey.

Wallasey Pool.—A most complete set of borings were taken by the late Mr. Rendel, C.E., preliminary to the construction of the Birkenhead Docks, and also by the Dock Board in 1855. To Mr. James Fosbery Lyster, C.E., I am indebted for an examination of the record plan on two occasions, and, from the information obtained, I have drawn three sections (figs. 6, 7, and 8). A to B is across the pool, commencing at the entrance of the Alfred Dock, and running in an irregular line nearly parallel to the sea wall beyond the entrance of the Morpeth Dock. C to D is at right angles to this, up the Low Water Basin nearly to the Great Float. E to F is from the Great Float towards the Morpeth Dock, nearly parallel to A B, but inclining towards it at the south.

From these sections it will be quite clear that Wallasey Pool not only was not the *Post*-glacial mouth of the Mersey, but that, perhaps with still more force, it is proved that it cannot have been the *Pre*-glacial mouth. The last supposition is one of those which have been from time to time put forward, but certainly in entire ignorance of the information I now lay before you.

The lowest part of Wallasey Pool is situated near or in the Low Water Basin, as shown in section C—D; but as we approach the Great Float there is a sudden rise from a to 15; and, as section E—F shows, the rock is continued across as a sort of shelf. It is possible that this particular part may show a cliff due to the winding about of the Pre-glacial stream; but whether this be so or not, the changes of levels on each side of it are certainly more gradual.

Borings west of the latter.—If we now direct our attention to the borings which Mr. Robert Bostock has kindly supplied me with, we find that, further west, in the course of Wallasey Pool, the rocky bottom is considerably deeper than in the sections at the mouth. The particulars are as follows. The positions of the borings have been marked for me on the 1-inch map of Cheshire by Mr. Bostock himself:—*

Wallasey Waterworks, No. 3— $\dfrac{23.00 \text{ s}}{57{\cdot}00 \text{ R}}$ 80 ft. clay & sand.

Copper Ore Yard, near Canada Works:—

No. 4— $\dfrac{23.00 \text{ s}}{61.00 \text{ R}}$ 84 ft. clay.

Beaufort Street, No. 5— $\dfrac{21.00 \text{ s}}{69.00 \text{ R}}$ 90 ft. clay and sand.

These borings are so considerably below the rock in section E—F, that the watershed must inevitably have been somewhere near this section line and the flow both ways therefrom; and this is also indicated by the inclination of the rock towards Leasowe Castle, where, according to Mr. Bostock, it was proved in Sir Edward Cust's well to be 180 feet below the surface.

The next sections, also from Mr. Bostock, are still more singular. They are as follows:—

Gilbertson's Mill, Cleveland Street:—

No. 6 (fig. 4)— $\dfrac{25.00 \text{ s}}{115.00 \text{ R}}$ 140 ft. of clay.

Brewery, Livingstone Street:—

No. 7— $\dfrac{25.00 \text{ s}}{115.00 \text{ R}}$ 140 ft. of clay.

Singleton's Mill, Price Street:—

No. 8— $\dfrac{25.00 \text{ s}}{110.00 \text{ R}}$ 135 ft. of clay.

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* None of these borings are marked on the lithographed map.

It will thus be seen that, unless there exists a deeper point between bores 3, 4, and 5, the portion of Wallasey Pool in which the rock is proved to be 115 feet below ordnance datum, is in a rock basin, as suggested to me by Mr. Bostock.

Bores 20 and 21, at Ford, respectively showing the rock about 38 feet and 55 feet below ordnance datum, also point to the conclusion that a line of watershed existed between the Cheshire valleys west of Birkenhead, and the Mersey, and that this line crossed Wallasey Pool.

Borings about Tranmere and Rock Ferry.—If we now turn our attention to some of the side valleys of the Mersey, we shall be additionally instructed. The examples are as follows, and are also supplied by Mr. Bostock:—

Scott's Foundry, Tranmere:—

No. 12— $\dfrac{20.00\text{ s}}{44.50\text{ R}}$ 64.6 clay.

Gas Works, Birkenhead:—

No. 13— $\dfrac{13.00\text{ s}}{38.50\text{ R}}$ 51.6 series of clay, sand, and gravel.

Railway, Old Chester Road:—

No. 14— $\dfrac{35.00\text{ s}}{13.00\text{ R}}$ 48.0 Ditto.

Corris, Joiner, Tranmere:—

No. 15— ——— 48.6 clay resting on gravel.

Hogarth, Builder, Limekiln Lane:—

No. 16— ——— 23.6 clay and sand.

Jones' Public House, Well Lane:—

No. 17— ——— 51.0 clay and sand.

Rock Ferry Park Lodge:—

No. 18— ——— 30.0 clay.

Bore No. 12 is probably near the centre of the mouth of a rock valley following approximately Tranmere Pool; but it would be rash to pronounce this to be the maximum depth, as unknown gullies sometimes exist, as I will show you further on.

Canada Dock.—Proceeding northwards, we next come to a series of borings taken in 1850, previous to the construction of the Canada Basin. Mr. Lyster supplied me with these, but it is unnecessary to go into an enumeration of them. The deepest of them (No. 19) is shown on the section of the river (fig. 1), and proves the rock close to the pier wall to be 44.15 below ordnance datum.

Huskisson Branch Dock.—An examination of these excavations last year showed the bottom of the dock to be a bed of gravel resting upon red sand, the *débris* of the rock below. Probably the rock here will be about the level of low water.

Garston Dock.—The last excavations I have to refer to are at the new Garston Dock. The rocky floor or old shore of the river was well displayed here. It formed a regular shelving piece of rock, covered with Boulder-clay, the level being below ordnance datum, as shown in plate 4, section 24, in my Post-glacial Geology of Lancashire and Cheshire. It gradually sloped towards the river.

INTERPRETATION OF THE DATA.

Having now put you in possession of most of my data, let us see if we can, with any accuracy, interpret the meaning of it all, and wrest still one more secret from Nature. In forming our opinions we must avoid hasty conclusions, and consider only what is the most probable explanation; always bearing in mind that our data is necessarily fragmentary and incomplete.

The first thing that attracted my attention, and indeed led me to gather information for further speculation, was the extreme depth of the rock-bed in the upper reaches of the river. Having borings both above and below Runcorn Gap, and Mr. Baker's Section of the Runcorn Gap Bridge, I was, as before explained, much puzzled to know whether the portion above the Gap was a rock-basin, like some of our northern lakes. If also, as is generally supposed, the present bed of the river from Prince's Dock to Seacombe is of rock, unless some other outlet were discovered, a second rock-basin would exist between the Gap and Seacombe Point. The possibility of Mr. Baker's Section being in error also occurred to me, as before stated; but the assumption of a gulley sufficiently deep in the Gap to connect the rock-beds by a regular gradient, such as would exist had the river flowed through it in Pre-glacial times, seemed, from the narrowness of the Gap compared with the extreme width of the river, both above and below, hardly warranted. Further information, however, presented an escape from these alternatives; and the borings at Widnes undoubtedly show that there exists, deep below the Drift on which the town of Widnes stands, a Pre-glacial gorge, connecting the rocky bed above Runcorn Gap with that below it, by a regular gradient. The disparity in size of the present and the Pre-glacial gorges is very apparent, and is well shown on section i—j (fig. 2.)

We have thus, on the assumption of a regular gradient to the Pre-glacial river at a time when the land was much higher with respect to the sea than at present, carried the river from Warrington down past the first obstacle. From thence, what the direction of its current was, is the next problem calling for solution. The subject is surrounded with difficulties, and the great expansion of width which takes place in the bend of the estuary between Frodsham and Ellesmere Port is one of them. There are many superficial appearances pointing towards the estuary having been a lake basin; but, unless we imagine an upthrow of the rock opposite Seacombe to have taken place since the channel and gorge existing between Ditton Brook and Warrington was excavated by a Pre-glacial river, this could hardly have been. If, then, we reject the idea of the Mersey estuary having been a Pre-glacial lake basin, we must either look for some other outlet than the present one, or believe that the channel is continued seaward from Runcorn Gap through the present gorge opposite Seacombe at a depth very much below that of the present bed. There is, however, still one more hypothesis, which doubtless will already have occurred to those familiar with Professor Ramsey's theory of the formation of lake basins in mountain districts, in which the scooping out of their rocky beds is attributed to the grinding action of glaciers. There are, as most of you are aware, undoubted evidences of the whole of the country, from Scotland to far south of Liverpool, having been covered by an ice-cap like that of Greenland at the present day. That this ice-sheet at one period moved approximately from north to south, is an opinion I share with Mr. Tiddeman and Mr. Close; but independently of the direction of the flow, it is of course perfectly legitimate to enquire if the ice, whether it descended the river, as conjectured by Mr. Morton, or crossed it, as conjectured by me, was an agent capable of sculpturing out the estuary as we now find it.

In considering this latter supposition, it will not do to lose sight of the tributary streams; and I think we have evidence from bore G at Sankey Bridges and the bores at Widnes, that the Sankey Brook, draining the country about and beyond St. Helens, and the Ditton Brook, draining the Childwall Valley, flowed into the Mersey with level beds at their confluences; and when we find in addition water-worn pebbles occurring so often lying just above the rock, we are also directed towards the same conclusion; for it is only natural to suppose that these have been worn round partly *in situ*, or at all events assorted into beds by currents; and in either case we are driven to the conclusion that either the sea had entrance, or the stream had an outlet. At all events, without declaring the thing impossible, even with the assistance of floating ice, it is difficult to account for water-worn gravel beds in the centre of a lake bottom. When inspecting the bore at Messrs. Gaskell, Deacon, & Co.'s Works, No. 4 (fig. 5), Mr. Timmins pointed out to me a heap of pebbles, which he says were taken from just above the rock. I collected the specimens I now submit, and which I have broken to show the nature of the rock. With the exception of the quartzite pebbles, of which there were a good many, and which are not improbably derived from the pebble-beds of the New Red Sandstone, the whole of the stones are travelled ones; and I think I can detect the Syenite of Carrock, in Cumberland, among them. The general character of the rocks is certainly that of the Lake District, and what we commonly find in the Lancashire Drift. In addition to Syenites, there are Greenstones, Felstones, and Mountain Limestone.

There is also another argument in favour of there having been an outlet, as against the lake basin theory; it is the comparative thinness of the red sand due to the grinding down of the Triassic rocks by the ice-sheet. I had often suspected the red sand, which sometimes underlies the Boulder-clay, to be due to this cause; but never, until I examined the Section at Bootle Lane Station, was this clearly proved. In that cutting, at the base of the clay, and lying upon the rock, from three to four feet of red sand occurred, containing no extraneous material. It consisted entirely of the local rocks, tightly compacted in places with rubble, which had apparently been pushed forwards and up hill by a force acting from the NN.W. At first sight it was difficult to distinguish it from the true rock, into which it apparently shaded; but a trowel or spade at any point showed it generally, though not invariably, resting upon a hard polished floor of the parent rock, free from striations, from the simple reason that there was nothing hard enough to create the groovings so often met with where the Boulder-clay lies direct upon the rock, without the intervening red sand. I shall return to this subject at some future time; but the discovery is of importance, as pointing out the equivalent of the Scotch Till, which was not before known to exist here.

If, then, this sand existed—or, rather, was produced—in very great quantities when the bed of the estuary was filled with ice moving southwards, what has become of it? It is not of so fine a nature that it could be carried by hydraulic pressure from underneath the ice, up hill, from out of a rock basin? Could it, then, have been pushed out? I think, to a certain extent, this may be conceded; but I am very much inclined to think that, had the estuary been a lake basin, it would have tended to fill it up; and, instead of our finding it a few feet thick in the lowest parts, or absent altogether, and the bed filled with Boulder-clay above 100 feet thick, we should have had a great accumulation of the *débris* of the Triassic rocks at the bottom. What, then, has become of the sand which certainly must have travelled across into the river bed? The most reasonable explanation, to my mind, is certainly this: that there existed a sub-glacial river, which carried most of the *débris* out seawards.

In Greenland streams of water course over the ice, and then suddenly plunge into a chasm and are lost to view, continuing their course under the great ice-sheet until they finally emerge at the sea.* I think it must be conceded that the present river follows the old drainage lines of the country, and when the ice accumulated, perhaps to thousands of feet thick, over the surface of the land, these old drainage lines would still direct the course of the waters; and the confined channels thus formed creating a river torrent, would urge stones under the ice and deepen its bed probably even faster than the ice could excavate a basin.

The present drainage area of the River Mersey is 1748 square miles;† and as there is no reason to suppose that the Pre-glacial drainage area was less, it naturally follows that any water running through the ice-cap within this area would flow into the old channel, and, in my view, would be amply sufficient to cut its way through the rocks at least as quickly as they were ground down by the slow-moving ice. I am of opinion, therefore, that the effect of the ice-sheet would be to widen the river and smooth off the curves of its bed; and perhaps, with the aid of the sub-glacial river, to deepen it also, by the removal of the detritus, in the shape of red sand caused by the abrasion of the Triassic rocks.

If, then, this reasoning be correct, we must seek for an outlet carrying the river seawards at a regular gradient. But where is this outlet to be looked for? And now, as we are advancing into the dangerous region of speculative geology, I desire that all I may say may be taken as merely suggestive, feeling strongly that it would be impossible to settle the problem without more data than I am in possession of.

It has with some people been a favourite occupation of the imagination to suggest all sorts of impossible courses for our river, even in historical times. We may, however, safely take it for granted that, ever since the laying-down of the Boulder-clay, its course has been precisely that which it follows now. In the main, the present was also the course of the Pre-glacial river; but we cannot pronounce the identity perfect through all parts of its course. We have seen the unexpected gorge at Widnes revealed by borings. How, then, can we say with certainty, seeing that the whole country is so thickly covered with Drift, that some other unknown channel may not exist? A course has been suggested by which the Mersey may have flowed into the Dee along the valley followed by the canal from Ellesmere Port. Unfortunately I have not been able to personally examine this district; but Mr. Robert Bostock, who has considered the subject, pronounces positively against this theory.

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* Nordenskiöld. *Geological Magazine*, Vol. ix, p. 361.

† Ramsey—"Physical Geology of Great Britain," p. 202.

Among the possibilities which have suggested themselves to me is that a channel may have existed below the present bed of the river, which, having been filled up with Drift, has never been re-excavated.

Against this supposition is, however, the prevailing opinion that a shelf of rock extends entirely across the river, from Seacombe Point to Prince's Dock. Being desirous of testing this, I have questioned several experienced master pilots on the subject, who are unanimous in declaring that there is no rocky anchorage in the fairway of the river; and, excepting a spur of rock a few hundred yards out from the Victoria Tower, they know of no rock below low water. That there is a shelf of rock across the river from Seacombe Point, they positively contradict. This evidence of anchorage is all the information we can get of the state of the river bed; and, to my mind, is reliable. If there is no exposure of rock in the river bed, it is quite open for us hypothetically to assume it to form a channel quite deep enough to drain the gorge.

Bearing upon this question, I exhibit the section of a rocky channel discovered in the excavations for the New Yarrow Reservoir, at Rivington; and we may thus see that, until we have actual proof to the contrary, the existence of such a deep channel, even if confined to a particular part of the river bed, is not an impossibility. The section which is drawn to the same vertical and horizontal scales will sufficiently explain my meaning. The excavations for the puddle wall of the embankment disclosed this unexpected gulley, and proved it to be 120 feet deep from the surface. It was, I believe, formerly the bed of the River Yarrow; but, becoming blocked up with Drift and moraine matter, the river changed its course, and now runs through another outlet.

My paper having already extended to a greater length than originally intended, I must leave unsaid much that I otherwise intended to say. Fortunately for geologists, a tunnel is now being driven under the Mersey which will eventually settle this point; so the best thing to do, perhaps, is to wait to see what it discloses. The subject is surrounded with difficulties, the data is insufficient to warrant absolute conclusions; we must therefore wait. I have laid certain facts before you which are, I hope, of some value. Of this, however, I feel pretty confident, that the evidence I have given, taken together with the absence of anything approaching the character of lacustrine deposits, proves that a natural outlet does somewhere exist. If the tunnel proves that it is not in the present bed, then I should look for it somewhere else. You will, however, judge for yourselves to what extent my theory is a probable one; and if anyone present can throw any new light on the question, it will afford me great satisfaction.

NOTE.—Since this paper was read, further consideration and observation have strengthened rather than otherwise, my opinion that there is a deep rock channel in the bed of the river between Liverpool and Birkenhead, notwithstanding what has been published to the contrary by the engineers of the Mersey tunnel. I am, however, quite resigned to wait for the actual proof.

FEBRUARY 11TH, 1873.

THE PRESIDENT, ISAAC ROBERTS, F.G.S.,
In the Chair.

The meeting was devoted to miscellaneous communications.

MARCH 11TH, 1873.

THE PRESIDENT, ISAAC ROBERTS, F.G.S.,
In the Chair.

The following communication was read:—

NOTES ON TRAVEL. — SOME GEOLOGICAL FEATURES OF THE AUSTRIAN TYROL.

BY ROBERT A. ESKRIGGE, F.G.S.

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WILSON, W. H., Aigburth.
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* Have read Papers before the Society.

ABSTRACT

OF THE

PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSION THE FIFTEENTH,

1873-4.

(The Authors having revised their papers, are alone responsible for the facts and opinions expressed in them.)

LIVERPOOL:
COURIER STEAM PRINTING WORKS, VICTORIA STREET.
1874.

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ABSTRACT OF THE PROCEEDINGS
OF THE
LIVERPOOL GEOLOGICAL SOCIETY.

SESSION FIFTEENTH.

OCTOBER 14TH, 1873.

THE PRESIDENT, ISAAC ROBERTS, F.G.S.,
in the Chair.

GEORGE STRONGITHARM was elected an Ordinary Member of the Society.

Anniversary Address by the President,
ISAAC ROBERTS, F.G.S.

VOLCANOES AND VOLCANIC AGENCY.

GENTLEMEN,

IN the spring of this year I had an opportunity of visiting the volcanic regions in the neighbourhood of Naples, and I propose now to give a brief *resumé* of what I saw and what I have learnt from various sources concerning volcanoes and volcanic agency.

Vesuvius stands preëminently amongst the two hundred or more active volcanoes which are known to be now, or have recently been, in existence, and may be considered as a type of the rest. It is the only volcanc with whose eruptive history we have been made familiar, at frequent intervals of time, before and since the commencement of the Christian Era; but that history (like other histories written by men who were only partially acquainted with their subject), does not satisfy the rigorous demands for exactness of the scientific mind of the present day. It differs, though from most other histories written during that epoch, inasmuch that religious or political zealots have not transformed the historical fragments into spacious falsehoods to suit their own or their parties' creed.

We can afford to overlook the fables of the St. Janarius type, and smile at the ridiculous paraphernalia that are publicly exhibited near Vesuvius, with the sanction of people high in office, who, even in these days, are not ashamed to try to perpetuate the mental slavery of an ignorant people. Fortunately, the days of these superstitions are numbered. Palmieri and his seismograph are at work; and we may hope, ere long, to have data which will enable us to foretell what Vesuvius is going to do, with the certainty with which an eclipse can now be predicted. But I am anticipating; for, I shall have more to say about the seismograph further on. I will now ask you to accompany me up Vesuvius, and, in order to assist your imagination, call your attention to the drawings and photographs which are hung on the board.

Having scrambled over the rough surface of the lava which was ejected last year during the eruption, we meet at the base of the cone with the first difficulty in attempting to ascend. The loose ashes which deeply cover the sides of the cone and form a slope at an angle of less than 40° with the horizon, give way under the pressure of the feet, so that at each step taken forward, or upward, we slip back again nearly half the length of the step; and after a few minutes' experience we feel, on looking upwards and calculating the distance we have yet to ascend, that our strength will be exhausted before reaching the summit.

At this juncture several men surround us, and with great importunity and persistence, offer their assistance. Three of them to each person generally succeed in getting themselves engaged; two to go before to haul with a rope, the end of which is held in the hands, and the other to push from behind. Their charge for this service, which does not exceed two hours' duration, is fifteen francs. But we may ascend in another manner, if we choose to indulge in the luxury of a stretcher. Then we shall be carried, wrong end foremost, upon the shoulders of four men, up to the top, and pay for this thirty francs. If we decline these services of both kinds, and show a determination to ascend without assistance, the men will still follow, hoping that our resolution will give way, until we ascend half-way up, when, if they see that we are still determined and our strength is unexhausted, they will leave, murmuring, and predicting that we will not survive the remainder of the journey; but with perseverance the summit of the cone will be reached in about 1½ hours, and then we may feel, somewhat proudly, that we have performed a feat that very few people have the courage to face unassisted.

Having reached the summit, we find the crater to be an irregular circle of about a quarter of a mile in diameter, filled with sulphurous vapour up to the brim. This ascends in dense white clouds high in the air. Occasionally we get a glimpse a little way down the slope, which is very steep (perpendicular in some places); but the interior of the crater has not been seen since the eruption of last year. There are small fissures near the edge of the crater, down which the heat still glows; and these minerals, the green colour of which is due to copper, were taken out of them in a hot state. These bombs, containing many crystals, I picked up amongst acres of similar ones, of all sizes, up to a foot in diameter, lying scattered upon the outer slope of the cone. The bombs appear to the eye to be compact; but when viewed under the microscope they appear vesicular, and show by unmistakeable evidence that they were ejected from the crater in a liquid state and assumed the crystalline and globular form when rising and falling through the air, in the same manner that molten lead falling through the air forms the shot used with guns.

From the elevated positions upon and about the cone, it is easy to trace the courses and extent of the lava streams of the last four or five eruptions. They are indicated on the drawing marked D. At Herculaneum and Pompeii the successive showers of ash or streams of lava may be traced on the slopes of the excavations, from that fatal shower that destroyed those cities in A.D. 79, up to the last shower that fell in modern times.

The descent of the cone is easy, each stride we take being nearly two yards in length; but if our boots are not strongly made, we will have occasion to seek for an early opportunity to procure another pair; and if the thread with which your dress is stitched is dyed with logwood black you will find it changed to a red colour for a day or two, and then to resume again its black colour. This is probably the effect of the gases which are now given off from the crater.

The cone undergoes a change of form after each eruption. Sometimes it is left low and flat, with a small cone in the interior of the crater; but it is now high, and the sides are steep.

The lava which has been ejected during recent eruptions is generally similar in structure to the specimens which I now exhibit. It is nearly all coarsely vesicular; very little of it is compact. The vesicles, of course, are formed by the steam and the gases which are excluded in the mass escaping after the lava is ejected from the crater and partially consolidated. You will, on examining these specimens, be reminded of the vesicular cavities formed in bread after fermentation, and still more striking is the similarity to some of the refuse slag that is thrown out from smelting furnaces.

The lava, as you will readily imagine, flows very slowly along the ground, unless it is flowing down a steep slope, near its source; but, instead of hardening with a comparatively smooth surface, like the surface of ice on a frozen stream, it is shattered into fragments, and nearly every fragment is tilted up at an angle with the slope at which it flowed. The reason of this breaking up of the lava appears to be the combined effects of the movement of the streams from a higher to a lower level, and the shrinking and cracking of the mass in cooling. The upper surface of the lava cools first, and forms archedways over the lower stratum, which is still viscid; these archedways afterwards break and fall in. The end of the stream, when it has flowed to some distance from its source, along the cold ground and exposed to the air, begins to solidify; but it is still being pushed from behind by the contiguous part which has not yet reached the same degree of solidity. Hence the semi-solid part, which offers sufficient resistance, is broken and tilted up; and so the process is continued backwards towards the source, until the eruption ceases and all is cold. Then we see the confused and rugged appearance, as shown on the photograph marked F.

There have been about 57 eruptions of Vesuvius recorded since the commencement of the Christian Era, and descriptions, more or less minute, have been preserved of several of them. Pliny the younger, who was an eye-witness of the great eruption of A.D. 79, to which allusion has already been made, gives a vivid description of it, together with its terrible effects upon the people and country about the mountain. A writer to the *Times* newspaper, dated 27th May, 1872, also gives a good account of the great eruption of last year.

The kind of materials which were thrown out by the eruption of A.D. 79 and 1872, respectively, will be seen by these specimens.

Leaving Vesuvius, we will visit the grottoes near Lake Avernus. First is the *Grotto del Cane*—a very small cave, closed in by a door, at which is a step descending about half-a-yard. A small fissure at the end of the cave admits carbonic acid gas in considerable quantities. It may be seen as a cloudy vapour, flowing out through the door over the step; it tastes strongly acid; it instantly extinguishes a lighted flambeau; and the little dog, when brought into the cave, immediately exhibits symptoms of suffocation, and seems very reluctant to undergo the experiment to which it is too often subjected.

Near the Grotto del Cane is another small cave, which gives off free ammonia; and near this cave is another, or rather three small caves, called *Stufe di san Germano,* where the temperature is like that of a hot room in a Turkish bath. Sulphurous vapour issues from the side, at a temperature of about 180° F., and deposits upon the sides the granular substance, a sample of which is in this bottle. Mr. Davis, F.C.S., to whom I am indebted for this and the other analyses, finds the yellow coating to consist of basic persulphate of iron. The flow of gases in the caves above described is affected by the eruptions of Vesuvius; we may therefore infer that an under-ground communication exists between them, although they are distant 14 miles from each other.

Leaving this locality, we will proceed eastward to Pozzuoli, and note the columns which are still standing and form part of the Temple of Jupiter Serapis. The bases of the columns are now at about the level of the sea, which is near. At the height of 10½ feet above the bases, they are deeply perforated by mollusca *(lithodomi)*. The height of the perforations on the shafts of the columns measures 8 feet. These facts reveal to us that since the temple was built—that is, a century or two before the Christian Era—the ground upon which it stands was submerged to a depth of more than 20 feet, and afterwards elevated to its present level. There are two hot springs within the enclosure, containing the ruins of the temple.

Near Pozzuoli is a semi-extinct volcano, called the *Solfatara*, the crater of which is a considerable plain, covered with trees. The sloping tufa walls of the crater form an amphitheatre, and the floor, when struck, sounds hollow, as if the throat of the volcano is empty and vaulted over. At one side of the crater is a small cavern, out of which issues sulphurous vapour, under considerable pressure, for it makes a loud hissing noise like that given by steam when escaping from the valve of a steam-boiler. The minerals, of which these are a sample, are deposited as an incrustation upon the roof of the cavern. They consist chiefly of sulphate of lime.

Alum is manufactured on a small scale in this crater, and these are samples of the state in which it is found in the fissures, as silicate of aluminium.

The only eruption of the Solfatara of which we have any record occurred in the year 1198, and its effects are traceable over a large extent of the surrounding country.

About two miles to the west of Pozzuoli is *Monte Nuovo,* the crater of an extinct volcano. This volcano, we are informed, broke out on the 29th September, 1538, and at that time the sea retreated from the Bay of Baiæ and Pozzuoli. The last elevation of the ground upon which stands the Temple of Jupiter Serapis above referred to was probably due to that cause. We have, therefore, the date of the occurrence, which took place 335 years ago.

Between Monte Nuovo and Baiæ are some galleries excavated in the tufa, at an elevation of several yards above the sea, in which are thermal springs and ruins of Roman baths.

Having now described at sufficient length for our purpose, the physical features of the volcanic regions about Naples, the question suggests itself, what are the causes of volcanoes? Many answers have been returned to this question, and some of them will appear to us very absurd. Aristotle, who lived about 2,200 years ago, was the greatest authority of his time and for centuries after. He says that "earthquakes are not caused by either earth "or water, but by wind. The exhalation of wind outwardly from the interior, or from underneath the "surface of the ground."

The theories of the Christians, or of those who theorised between the first and the eighteenth centuries of the Christian era, may be roundly stated as that earthquakes and volcanoes were the works of Satanic agency, and required the intercessions of saints and priests, besides liberal bequests to the Church, to overcome their evil influence.

But in the year 1760 the Rev. John Mitchell, of Cambridge, threw a little of the light of science upon the subject in a paper published in the Philosophical Transactions. He said that "an earthquake was a sudden "lifting up, by a rapid evolution of steam or gas beneath, "of a portion of the earth's crust, and the lateral transfer "of this gaseous bubble beneath the earth's crust, bent "to follow its shape and motion, or that of a wave of "liquid rock beneath, like a carpet shaken on air." The source of the lifting power being molten matter to which water has access.

The opinions of the scientific men of our own times may be stated as follows:—The primary causes of earthquakes and volcanoes are the samè, namely, development of heat and chymical action at various depths in the earth. The earth is supposed to have originally been in a state of igneous fusion, and to be gradually cooling, the interior being still in a molten state. Upon this fluid core rests the solid crust, having a thickness not exceeding one thousand miles, some think only fifty miles or even less. As the fluid core cools, it contracts, or lessens in bulk, and so leaves the solid crust unsupported; it then breaks, falls down, fissures, and gives rise to earthquakes and volcanic phenomena. Some think there are lakes of molten matter at various depths in the crust of the earth, to which water finds access, and thus gives rise to earthquakes and volcanoes.

These theories rest at present upon insufficient evidence; we must, therefore, accept and value them only as speculations. Another theory has recently been elaborated by Mr. Robert Mallet, C.E., who has for many years devoted much time and thought to the consideration of this subject. His reports to the British Association for the Advancement of Science, commencing in the year 1850, contain an exhaustive history of earthquakes and volcanic phenomena from the earliest historical times to the present.

He defines an earthquake as "the transit of a wave "of elastic compression, in any direction, from vertically "upwards to horizontally, in any azimuth, through the "surface and crust of the earth, from any centre of "impulse, or from more than one, and which may be "attended with tidal and sound waves dependent upon "the impulse, and upon the circumstances of position "as to sea and land."* Mr. Mallet has determined by experiments, conducted with great care, the velocity at which waves produced by impact pass through strata composed of various kinds of rock, shale, and sand, such as form the crust of the earth. The velocity appears to be from 900 to 1,700 feet per second. He computes the depth of the force which caused the great Neapolitan earthquake of 1857 at seven to eight geographical miles below the level of the sea.

But the point in Mr. Mallet's theory, to which I wish to direct your attention, is the application of the law recently discovered of the mechanical equivalent of heat, to account for the cause of volcanic phenomena. He performed a series of experiments in crushing cubes of Caen stone, Portland stone, limestones, slates, basalts, granites, and porphyries; and from the force expended upon the cubes in these experiments, he found that the heat developed, in crushing one cubic foot of the stones respectively, varied from 331 to 7,867 British units.

From these data the following result may be deduced —that if one cubic mile of such rocks as form the earth's crust be crushed to powder, sufficient heat would be developed in the operation to melt nearly 3½ cubic miles of such rock. In the application of this theory, which bears on the face of it a scientific look, Mr. Mallet is obliged, in establishing his own theory, to adopt the theory of his contemporaries, namely, that the earth's interior is in a molten state, and that the melted core is still cooling and contracting, or he could not find a force to produce the secondary heat, by the falling and crushing of the crust, to give rise to volcanic phenomena.

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* Report British Association, page 2.

If we are satisfied with the evidence adduced, that the interior of the earth is in a molten state—that it is cooling, and therefore contracting—that the crust is comparatively thin and will break when unsupported from beneath, then Mr. Mallet's theory will fulfil the other conditions requisite in accounting for the matters ejected by volcanoes without violating the laws of hydrostatics, which some other theorists do with impunity.

What, then, is the evidence upon which is based the theory that the earth was once a ball of liquid fire, and that the interior is still so? Firstly, it is found that the temperature of the crust increases 1 deg. Fahrenheit for about every 65 feet in depth; and if this increase in temperature is constant towards the centre, from the depths at which experiments have been made, the melting point of iron would be reached at the depth of about 34 miles from the surface, and by adding this increment of heat, for a depth of, say, only 200 miles below the surface, a heat so intense would be reached as to re-fuse the present crust. This consideration shows that there is some radical error in the theory.

Again the spectroscope, within the last few years, has revealed to us that the sun is an incandescent globe, where elementary substances in every respect similar to those which exist in the earth are converted into luminous vapour. There is, therefore, now no difficuly in the conception of the theory, that the earth also may have been in times remote a self-luminous globe—a pigmy sun, diffusing its light and heat into space until its energy for so doing was exhausted.

Countless millions of years must have elapsed since then, yet the fiery mass has not cooled to the centre, and possibly only a comparatively thin crust exists between the surface and the molten interior.

The geologist can form conceptions of time more vast than probably any other student of Nature, but the time since the deposition of the comparatively modern Trias is too vast for his faculties to grasp. He can more dimly still see down the vista, towards the period of the deposition of the Laurention, but what conception can he form of the time which has elapsed since the earth was an incandescent globe?

I shall now direct your attention to some of the scientific methods which have been introduced and instruments, recently constructed with the object of enabling observers to examine, with mathematical exactness, the direction, intensity, and other circumstances attendant on earthquake shocks.

The drawing on the board shows some of the instruments which I had the honour of examining and having fully explained to me at Professor Palmeri's observatory near the foot of the cone of Vesuvius. There are also other instruments for measuring and registering the electrical phenomena, both aërial and terrestrial.

By these means the following data are obtained, and a register of them is carefully kept:—

1. Any vertical movement of the ground, together with its extent and duration.

2. Any horizontal movement, with its direction, intensity, and duration.
3. The conditions of aërial and terrestrial electricity.
4. The assistant being always present and forewarned by the instruments, notes any phenomena that are visible to the sight. The registers are posted up regularly three times a day, and after the lapse of a sufficient interval of time they will form truthful data, for some physicist in the future, to deduce from them the laws which govern earthquakes and volcanoes.

I will only add that not Vesuvius only, but several other volcanic centres in different parts of the globe, must have their observatory, seismographs and skilled attendants, to keep faithful records of the volcanic movements; and all these must be, by the electric telegraph, placed in instantaneous communication with each other before the means at our disposal are fully utilised, in obtaining data for evolving the laws which govern those phenomena that have produced such mighty changes on the surface of the globe.

The expense attendant upon the instruments and stations here proposed, would be but a trifle even if England alone undertook the duty; but if the subject were taken up by men of science, other countries would doubtless gladly claim the honour of contributing their share; and thus another giant stride would soon be made in elucidating the cosmogony of the earth and enlightening our darkness.

NOVEMBER 11TH, 1873.

THE PRESIDENT, ISAAC ROBERTS, F.G.S.,
in the Chair.

The first part of the following communication was read:—

THE CARBONIFEROUS LIMESTONE AND MILLSTONE GRIT OF NORTH WALES.

LIST OF WORKS RELATING TO THE SUBJECT.

• BY GEORGE H. MORTON, F.G.S.

The author does not pretend to have made a complete List, and will therefore be glad to hear of any Papers that are unnoticed.

1778.

PENNANT, T.—"Travels in North Wales."

1816.

CLARK, E.D., LL.D., F.G.S.—"Analysis of One Hundred Parts of Dark Bituminous Limestone, from the Parish of Whiteford, in Flintshire, North Wales."—*Trans. Geol. Soc.*, Ser. 1, Vol. iv., p. 430.

1822.

CONYBEARE, Rev. W. D., F.G.S., and PHILLIPS WILLIAMS, F.L.S.—"Outlines of the Geology of England and Wales."

1829.

YATES, Rev. JAMES, M.A., F.G.S.—"Observations on the Structure of the Border Country of Salop and North Wales, and of some Detached Groups of Transition Rocks in the Midland Counties." (*Read* 1825.)—*Trans. Geol. Soc.*, Ser. 2, Vol. ii., p. 237.

1839.

MURCHISON, Sir R. I., F.G.S., &c., &c.—"The Silurian System."

1841.

Bowman, John Eddowes, F.L.S.—"Notes on a Small Patch of Silurian Rocks to the West of Abergele, on the Northern Coast of Denbighshire." (*Read* 1838.)—*Trans. Geol. Soc.*, Ser. 2, Vol. vi., p. 195. An Abstract in *Proc. Geol. Soc.,* Vol. ii., p. 666.

1846.

Sedgwick, Rev. Prof. A., F.G.S—" Outline of Geological Structure of North Wales." (*Read* 1843.)—*Proc. Geol. Soc.*, Vol. iv., p. 212.

Sedgwick, Rev. Prof. A., F.G.S.—"On the Older Palæozoic Rocks of North Wales."—(*Read* 1843.)—*Proc. Geol. Soc.*, Vol. iv., p. 252.

Sharp, D., F.G.S.—"Contributions to the Geology of North Wales."—(*Read* 1844.)—*Jour. Geol. Soc.*, Vol. ii., p. 283.

1850-7.

Government Geological Survey; Maps and Sections of North Wales.

1856.

Haughton, S., Rev., A.M., F.G.S., Prof. Geol., Trin. Coll., Dublin.—"On the Nearer Palæozoic Rocks which border the Menai Straits in Carnarvonshire." (*Read* 1853.) *Jour. Geol. Soc. of Dublin*, Vol. vi., p. 1.

1857.

Moissenit, M. L., Ingenieur des Mines.—"Mémoir sur le Gisement du Minerai de Plomb, dans le Calcaire Carbonifèra du Flintshire."

1862.

Duckworth, H., F.G.S.—"Report of the Excursion made by the Society to Holywell, July, 1861."--*Proc. L'pool Geol. Soc.*, Vol. i.

1864.

Davies, D. C.—"Geology and Botany of the District" in *Roberts' Llangollen Guide*, p. 53."

1865.

Davies, D. C.—"The Mountain Limestone of North Wales." (*Read* 1861.)—*Oswestry and Welshpool Naturalists' Field Club*, 1865, p. 50.

Prosser, W., F.G.S.—"The Fossiliferous Character of the Millstone Grit at Sweeney, near Oswestry, Shropshire."—*Geol. Mag.*, Vol. ii., p. 107.

Maw, G., F.G.S.—"On some Deposits of Chert, White Sand, and White Clay in the Neighbourhood of Llandudno, North Wales."—*Geol. Mag.*, Vol. ii., p. 200.

Maw, G., F.G.S.—"Letter on a White Sand Deposit at Talargoch Mine, near Prestatyn, Flintshire, North Wales."—*Geol. Mag.*, Vol. ii., p. 428.

Maw, G., F.G.S.—"Permian Strata of the Vale of Clwyd."—*Geol. Mag.*, Vol. ii., pp. 380, 523.

Davies, D. C.—"Denudation, Unconformability, and the Vale of Clwyd."—*Geol. Mag.*, Vol. ii., p. 476.

Davies, D. C.—"The Outlier of Carboniferous Limestone near Corwen, North Wales."—*Geol. Mag.*, Vol. ii., p. 283.

Jukes, J. B., Prof., F.G.S.—"The Outlier of Carboniferous Limestone near Corwen."—*Geol. Mag.*, Vol. ii., p. 326.

1866.

Ramsay, Prof., LL.D., F.G.S.—"The Geology of North Wales."—*Memoirs of Geol. Survey*, Vol. iii.

1867.

Green, A. H., M.A., F.G.S.—"On the Lower Carboniferous Rocks of North Wales."—*Geol. Mag.*, Vol. iv., p. 11.

1869.

Morton, G. H., F.G.S.—"Palæontological Observations on the Carboniferous Limestone in Flintshire."—*Proc. L'pool Geol. Soc.*, Vol. i.

1870.

Davies, D. C.—"On the Millstone Grit of the North Wales Border."—*Geol. Mag.*, Vol. vii., pp. 68 and 122.

Aitken, J., F.G.S.—"The Grit-rocks of the Eastern Border of North Wales."—*Geol. Mag.*, Vol. vii., p. 263.

Morton, G. H., F.G.S.—"The Mountain Limestone of Flintshire and part of Denbighshire."—*Report Brit. Ass.* for 1870, p. 82.

1873.

Morton, G. H., F.G.S.—"The Strata below the Trias in the Country around Liverpool, and the probability of Coal occurring at a moderate depth."—*Proc. Lit. & Phil. Soc. of L'pool*, Vol. xxvii., p. 157.

Davies, D. C., F.G.S.—"On Coal Seams in the Permian at Ifton, Shropshire."—*Proc. Geol. Ass.*, Vol. iii., p. 138.

(The further publication of this paper unavoidably postponed until the next session.)

DECEMBER 9th, 1873.

The President, ISAAC ROBERTS, F.G.S.,
in the Chair.

William Goldsworth was elected an Ordinary Member of the Society.

The following communication was read:—

NOTES ON THE PHENOMENA OF GLACIAL ACTION IN NORWAY.

By J. A. Picton, F.S.A.

Having for some years paid attention to the evidences of glacial action in the valleys of North Wales, I was glad of an opportunity during the present year of comparing notes with similar phenomena on a much grander scale in the southwestern district of Norway. As the conclusions at which I have arrived tend to modify in some respects the received theories on the subject, I venture to submit the following observations, in order that their soundness may be tested by free discussion.

There is no force in Nature which has played a more important fact in fitting the earth's surface for the purposes of animal and vegetable life, than water in the form of ice. It has scooped out our valleys, ground down the hardest rocks, and triturated them into sand and clay, which the torrents and lakes which it has generated have distributed over the lower lands. The undulations which impart beauty, and the soil which gives fertility to the landscape, are to a very large extent due to the action of ice in the form of glaciers.

The evidences of this action in the mountain districts of our own country abound on every side, and form a most interesting field of inquiry. The results however, satisfactory as they may be, are still only matters of inference, and require confirmation from the observation of glacial phenomena in action at the present time.

The glaciers of Switzerland, from their magnificent scale and their easiness of access, have attracted the largest amount of attention, and have been illustrated by the observations of many eminent men, such as De Saussure, Agassiz, Forbes, and Tyndall. We are, therefore, tolerably familiar with their formation, structure, rate of motion, and other attendant circumstances. The Swiss glaciers are present existing facts, and can only be studied, as it were, from the outside. Could we imagine the various ice-streams radiating from the huge centre of Mont Blanc suddenly removed, and the results of their action in the depths of the valleys laid bare, we can easily conceive what light would be thrown on various problems which have occupied the minds of scientific men. Now, this is precisely what we find in Norway. The existing snow-fields and glaciers are interesting in themselves; but, connected as they are with palpable evidences of similar action at a period incalculably remote, and on a scale of most stupendous grandeur, the study of the phenomena acquires an importance which, in the interests of geological science, can hardly be over-estimated.

There is also another source of interest. The Swiss glaciers change very little in their external aspect. Lyell says of them:—"The terminal point remains usually unchanged from year to year, although every part of the ice is in motion, because the liquefaction by heat is just sufficient to balance the onward movement of the glacier, which may be compared to an endless file of soldiers pouring into a breach, and shot down as they advance."

This is not literally accurate, as there is evidence that several of the Swiss glaciers—for instance, that of the Rhone, and the Mer de Glace in the Vale of Chamounix—have receded to some extent; but in Norway many of the glaciers are, so to speak, in lively motion, advancing and receding with enormous strides, and enabling us to compare the present phenomena with the results of former ages, in a manner at once interesting and accurate.

The peculiarity of the Norwegian scenery consists in the fact that the present glacial phenomena are connected, without any break of continuity, with those of a remote geological period, which have left behind results of most remarkable character.

For the better comprehension of what follows, I will here transcribe a few remarks on glaciers, from the latest and most eminent writers on the subject.

Sir Charles Lyell says*:—"In the temperate zone the snow lies for months in winter on the summit of every high mountain, while in the Arctic regions a long summer's day of half-a-year's duration is insufficient to melt the snow, even on land just raised above the level of the sea. It is, therefore, not surprising, since the atmosphere becomes colder in proportion as we ascend in it, that there should be heights even in tropical countries where the snow never melts. The frozen mass, augmenting from year to year, would add indefinitely to the altitude of Alpine summits, were it not relieved by its descent through the larger and deeper valleys to regions far below the general snow-line. To these it slowly finds its way in the form of rivers of ice called glaciers, the consolidation of which is produced by pressure and by the congelation of water infiltered into the porous mass, which is always undergoing partial liquefaction, and receiving in summer occasional showers of rain on its surface. In a day of hot sunshine or mild rain, innumerable rills of pure and sparkling water run in icy channels along the surface of the glaciers, which in the night shrink and come to nothing. They are often precipitated in bold cascades into deep fissures in the ice, and contribute together with springs to form torrents, which flow in tunnels at the bottom of the glaciers for many a league, and at length issue at their extremities from beneath beautiful caverns or arches. The waters of these streams are always densely charged with the finest mud, produced by the grinding of rock and sand under the weight of the moving mass."

In respect to moraines, the only observation made by Sir Charles is, that "the stones carried along on the ice are called in Switzerland the *moraines* of the glacier.

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* "Principles of Geology." 8th edit. 224.

There is always one line of blocks on each side or edge of the icy stream, and often several in the middle, where they are arranged in long ridges or mounds, often several yards high."

Professor Tyndall, the latest and probably the most scientific authority on the subject, thus treats of the moraines:—

"The glacier is flanked by mountains, which are washed by rain, dislocated by frost, riven by lightning, traversed by avalanches, and swept by storms. The lighter *débris* is scattered by the winds far and wide over the glacier, sullying the purity of its surface. Loose shingle rattles at intervals down the sides of the mountains, and falls upon the ice where it touches the rocks. Large rocks are continually let loose, which come jumping from ledge to ledge, the cohesion of some being proof against the shocks they experience, while others, when they hit the rocks, burst like bombshells and shiver their fragments on the ice."

"Thus the glacier is incessantly loaded along its borders with the ruins of the mountains which limit it, and it is evident that the quantity of rock and rubbish thus cast upon the glacier depends upon the character of the adjacent mountains. Where the summits are bare and friable, we may expect copious showers; where they are resistant, and particularly where they are protected by a covering of ice and snow, the quantity will be small. As the glacier moves downwards, it carries with it the load deposited upon it. Long ridges of *débris* thus flank the glacier, and these ridges are called *lateral moraines.* When two tributary glaciers join to form a trunk glacier, their adjacent lateral moraines are laid side by side at the place of confluence; thus constituting a ridge, which runs along the middle of the trunk glacier, and which is called a *medial moraine*. The rocks and *débris* carried down are finally deposited at its lower extremity, forming there a *terminal moraine*."

"When a glacier diminishes in size, it leaves its lateral moraines stranded on the flanks of the valleys. Successive shrinkings may thus occur, and *have* occurred at the intervals of centuries; and a succession of old lateral moraines, such as many glacier valleys exhibit, is the consequence. . . . The glacier may also diminish *in length* at distant intervals; the result being a succession of more or less concentric terminal moraines. In front of the Rhone glacier we have six or seven such moraines, and the Mer de Glace also possesses a series of them."*

I have quoted thus copiously from the latest and highest authorities on the subject of glaciers, in order that the views of these eminent men may be fully understood. From the observation of the ancient moraines left in many of our valleys, I have long been of opinion that the causes here assigned are in themselves insufficient to account for the effects. The terminal moraines described by Professor Tyndall, and such as we now see at the foot of any of the Alpine glaciers, consist almost entirely of rough boulders, intermixed in some cases with coarse gravel, the soluble portions of clay and mud being carried away by the torrents which always issue from the base of the glacier.

The ancient moraines in the valleys of Wales and Scotland, as well as those of Norway, consist of confused masses of *débris*, comprising boulders of all sizes, and erratic blocks of large dimensions, embedded in gravel, clay and soil of the loosest and most friable consistency. Had these been the result of the ordinary terminal moraine, all the soil, clay, and soluble matter must have been washed away, leaving only the boulders and heavier blocks.

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* "The Glaciers of the Alps, 1860," p. 263 et seq.

The moraine spanning the valley of Hildal, at the head of the Sör fiord, extends about a mile across the valley, with a breadth of more than half-a-mile and a height of about 200 feet, consisting of the *débris* I have just described. It is impossible to conceive that this vast mass can have been heaped together by the mere droppings from the end of the glacier. The accumulation of soluble clay and soil would be altogether unaccounted for.

With the solution of this problem in view, I was glad of an opportunity of visiting the Norwegian valleys, where many of the glaciers, instead of remaining in the quiescent state of those in Switzerland, are in active motion, advancing or receding, and laying open to practical observation the action of the forces by which they are governed.

As an illustration of this kind, I paid a visit to the Buerbræ glacier, which has been advancing during the last three years down the valley with rapid strides. This glacier is situated in a lateral valley opening from the Hildal near the head of the Sör fiord, which is a branch of the great Hardanger arm of the sea. The valley of Hildal, I have already said, is a continuation of the fiord, and is crossed at its mouth by an enormous ancient moraine. Beyond this lies the Sandven Lake, from which issues a considerable river, which has cut through the moraine, and formed a beautifully undulating and fertile valley. The lake and upper valley are lined by precipitous mountain sides rising to the height of 3,000 feet, above which rises the snow range. The rounded *roche moutonée* rocks occupy the sides of the valley, to the height of the ancient glacier, above which the tearing effects are visible in the rugged splintered aspect of the upper rocks, over which waterfalls of every shape and character pour down floods from the snow fields above. There are great numbers of erratic blocks of very large size strewed along the valley. Many of these have doubtless been detached from the cliffs above, since the glacial period, but many of the earlier ones have been torn off by the skirts of the glacier and left stranded, where a turn in the valley, or a widening out of the space dimished the tractive force. In the moraine crossing the valley, I observed erratic blocks 50 feet long, 20 feet wide, and 15 feet in depth.

The Buerbræ valley opens laterally from the Sandven Lake, and is one of the outlets from the Folge Fond, a snow-covered plateau, 35 miles in length by 15 in width. As the mountains rise so precipitously from the lake, the Buerbræ is only accessible by water. From the lake to the foot of the glacier, the distance is about three miles, all of the same grand character of scenery. The path is rugged but not difficult, and is practicable for a Norwegian horse. The geological formation is gneistic grey granite, with a certain appearance of stratification, and intersected by numerous quartzose veins.

The glacier extends across the upper end of the valley, at a point where there is a turn in its direction. It presents a front of about 100 feet in height. It is stated, that it has advanced about 300 feet in three years, and this was confirmed by my fellow traveller, who had visited the locality three years before. During these three years, the glacier has destroyed and absorbed into its icy bosom, the greater part of a farm in the valley.

We have therefore, here in actual operation, the mighty power, the result of which elsewhere, we can only infer from subsequent phenomena. The appearance of the glacier is peculiarly striking. Owing to its position, the moraine on its upper surface has been tilted over to one side, leaving the advancing front perfectly clear and pellucid. The colour in the crevasses, and thinner walls and crests, is a pale bluish green; the solid portions pure white. The consistency much resembles that of coarse Carrara Marble. When detached pieces are handled, they disintegrate into crystals, and in no part did I observe pure homogeneous ice. The advancing mass forms a ridged surface down the valley. From the ridge, crevasses or furrows extend laterally in curved lines, indicating the quicker movement of the central part. The whole appears endowed with life and motion. From innumerable furrows, crevasses, and salient points, thousands of little streams are constantly flowing, showers of stones from time to time are thrown off loosened by the dissolving ice, and below rushes out direct from the glacier, a roaring torrent constituting a formidable river.

Now as to the effects and the phenomena of its advance. The front of the mass having something of a pointed form, the whole assumes the character of a gigantic ploughshare, tearing up and driving before it with irresistible force, earth, rocks, trees, and everything it approaches. It has already raised a considerable moraine in front, of perfectly fresh material, which it is pushing forward year by year. The erratic blocks which it meets with, many of them of very large size are either pushed forward, or absorbed, to be deposited elsewhere.

The material of which this moraine is composed, corresponds exactly with that of the ancient moraines to be met with in Norway, and in the valleys of Wales and Scotland, and is entirely different from the boulder stones and gravel brought down by the glacier. Reasoning from similar effects to similar causes, it is only fair to infer, that these ancient moraines have been formed in the same way. It would appear from observation, that there are several kinds of moraines, according as they are formed by an advancing, stationary, or receding, glacier. This fact, which seems scarcely to have been noticed, will be found very important in accounting for existing phenomena.

I have described the present condition of the Buerbræ glacier in its state of advance; I will now refer to another Norwegian glacier, which after a considerable advance, has again shrunk within less than its former limits. I quote from Professor Forbes's work on Norway and its glaciers. (1853), p. 168.

The Nygaard glacier in Justedal, in the early part of the last century, advanced considerably down the valley. Since the year 1742 it has been retreating, and has now receded from 1700 to 2000 feet from the ultimate point which it reached. The Professor says, "Here we have evidence of the immense fluctuations in dimension to which glaciers are subject within periods by no means remote, probably more striking than is anywhere to be found in Switzerland." The most inexperienced eye perceives at a glance the alternations which have taken place. "Where the glacier, in retreating, quits the contact of rock on either side, its ancient limit is marked by the mound of fresh coloured debris which it has driven before it to the utmost bound of its overflow, and which remains there a monument to future ages of its vast extent. All the semilunar space included between this moraine and the existing ice, a plain of enormous extent, is emphatically *waste.* It is almost level, and absolutely covered with rolled stones of every size from that of an egg to blocks of several cubic yards, *loose and free from any cohering soil.*" The last observation, as to the absence of any soil in the debris of the retreating glacier, it will be important to bear in mind.

When a glacier is advancing, tearing up the soil and pushing before it a confused mass of debris, it is of course an indication of a diminished temperature, and of the ice accumulating behind faster than it melts in front. The water, which always flows in a greater or less degree from the foot of the glacier, will find an outlet at one side, leaving the great mass of the moraine intact, as is at present the case with the Buerbræ glacier. This may be called the *base* moraine.

If the glacier is stationary, in the words of Sir Charles Lyell, "the liquefaction by heat is just sufficient to balance the onward movement of the glacier;" the stones, rocks, and rubbish ground away by the movement of the ice being carried along the surface, eventually fall over the front and form a pile of rough blocks of boulders and gravel, any soil, mud, or soluble matter being carried away by the torrent issuing from below. This is the *surface* moraine.

If the glacier is receding, the action will be necessarily modified. Instead of accumulating in a heap at the foot of the terminus, the blocks and detritus will be spread over the valley in the manner described by Professor Forbes in the Nygaard valley already quoted. This may be called the *retreating* moraine.

One more remark before I proceed to apply the principles thus laid down. In the case of the Buerbræ, the valley below the glacier bears unmistakeable marks of glacial action at a remote period. Since that period, which must be very distant, the action of the elements by frost and rain, and running water, has silently and insensibly, age after age, been at work disentegrating the granitic rocks, and strewing the valley with mud, sand,

and gravel. Vegetation has succeeded, and layer after layer of soil has been formed, in which generation after generation of plants have lived and died, and formed a pabulum for the forests of pines which here flourish in luxuriance up to the very edge of the ice barrier. Then, impelled by the mysterious influence of climate, the glacier again advances, and roots up and destroys, with ruthless force, the green garment of beauty with which nature has clothed the waste.

With these facts before us, and the influences reasonably deducible from them, we are now in a condition to draw general conclusions from the glacial phenomena on a more extended scale.

The Western districts of Norway, to which I wish to call attention, present picturesque features of a character almost unique. The fiords, or arms of the sea, run up into the interior upwards of a hundred miles, with lateral branches ramifying to such an extent, that salt water navigation is brought into the very heart of the country. Many of these branches are narrow lanes of water, of almost unfathomable depth, their steep sides rising nearly perpendicular to the height, in some cases, of 5,000 feet. From the termination of the fiords narrow valleys extend to the summit level, possessing much of the same character of savage grandeur, expanding occasionally into extensive fresh water lakes. From the escarped sides of these valleys innumerable waterfalls pour down a never failing and superabundant supply.

The Keel Foss, on the Sör Fiord, is 2,000 feet high, and some of the falls, such as the Vòring and Skœggedal, are amongst the finest in the world. Norway is emphatically the country of water. On every side, either in the form of snow, ice, lakes, cascades, rivers, or fiords, water is the essential feature of every landscape, and *imparts* life and vigour to the view

These long narrow fiords are simply valleys of denudation, scooped out by ice, and sunk below the level of the sea. In the *roches moutonées*, which are half immersed in the water, and in the jagged and splintered sides, unmistakeable marks of glacial action are visible on every hand.

The geological base throughout the greater part of Norway is granite and porphyry, passing into stratified gneiss, with schistose strata in places superimposed.

At the head of the fiords a huge moraine usually crosses the valley, behind which is a lake, the river issuing from which has cut through the moraine. In some cases the river has drained the lake, which has become converted into fertile land. The lateral valleys, opening from the main lines, are usually closed also by a moraine.

Another feature of Norway is the extensive table lands covered with snow fields, such as the Folge Fond, the Fille Fjeld, and the Doyre Fjeld. Some of these are fifty miles in length by twenty in width. From these descends the supply of nevé, or half melted snow, which feeds the glaciers which occupy the higher valleys.

On a cursory glance at the general features of the Norwegian landscape, it is quite evident that at some remote period glacial action has prevailed on a scale, and to an extent which almost overwhelms the mind by its grandeur. The fiords, which are now in some cases of almost unfathomable depth, must have been subaerial valleys, filled with ice, of which the polished and rounded base rocks and the rugged steep sides still exhibit the proofs. Now the moraines, which are found at the entrance of the valleys opening to the fiord, must of necessity mark the termination of the glacier to which they owe their origin. How then can we account for the ice action in the fiord itself?

Again, the moraines in question are *base* moraines, that is, they have been, from the nature of their materials, the detritus of valleys covered with soil and vegetation. How can this be made to accord with the stupendous force which in the first instance tore away the rocks and ground out the valleys. The original denudation of the valleys must have removed material fifty times as great in quantity as is deposited in the moraines, and yet these moraines are evidently the limit to which the operations at the glaciers extended.

The answers to these questions will, I think, be found in a chain of reasoning fairly deducible from the phenomena.

In order to account for the manifest glacial action in the fiords, it is necessary to suppose them originally above the level of the sea. There must have been the necessary slope for the glaciers to descend by their own gravitation. This would elevate the whole surface of the land by many hundreds, perhaps thousands, of feet. In this condition the country would very much have resembled Greenland at the present day, where the glacial valleys descend to the sea, and discharge the enormous icebergs which dot the surface of the North Atlantic in the summer. The rounded and polished character of the rocky islands in the open part of the fiords gives countenance to this view.

Let us now suppose in the course of ages the land slowly depressed, and the climate ameliorated. The lower valleys are sunk beneath the sea, and converted into fiords; the upper valleys, strewed with the detritus of the receding glaciers, become gradually clothed with vegetation under the benign influence of the milder temperature. But a change again takes place, by which the climate becomes more severe. Again the glaciers advance, ploughing up their way down the valleys, carrying destruction before them, and heaping up the enormous mounds now visible. When they reach the edge of the sea the milder climate arrests their course, and they again gradually retreat. In this retreat, behind the moraines they have formed, the first result from the increased liquefaction will be the formation of a lake, the water being dammed up by the mound, until the increased pressure bursts the barrier and a torrent is formed, carrying off the superfluous waters into the fiord. The glacier still retreats, strewing the valley as it recedes with the spoil from its surface, until it finally shrinks within its present bounds, and the valley in the course of time gathers soil and recovers its fertility.

This hypothesis receives countenance from what we see of the operations of Nature at the present day in the changing aspect of the glaciers in Norway. In addition to those already mentioned, the Bondhuns glacier, situated on the Hardanger fiord, has retreated three miles from its original limit, and has left behind a moraine of the same character as those above described.

Professor Forbes, in his work on Norway, makes the following remarks; which, although they do not push the inferences to their legitimate conclusion, yet, as far as they go, fully bear out all that has been above advanced.

He says—"I will state some considerations which seem to lessen or remove difficulties which have been urged against the opinion that Norway was once *nearly* covered with snow and ice. That this was really the case is, I think, rendered probable by the facts so well described by Esmark,* as well as by the grooving and polishing of the valleys connected with the great plateaux in the direction of their declivities, and by the evidence for a limit to the height of the abrading action, which lowers as we approach the coast, and is marked by the contrast of the *roches moutonées* below, with the rugged peaks which rise over them. To these may be added the existence of moraines, especially terminal moraines; and though I speak conjecturally, I have little doubt that the terraces are due, in some degree at least, to the continuous moraines of ancient glaciers, descending from the mountains still partially covered with perpetual snow. Such moraines almost invariably produce lakes; and it is well known that a chain of lakes at nearly equal heights above the sea, interrupt the course of the numerous rivers of that wide and desolate country."

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* Professor Esmark, of Copenhagen, published in a Danish periodical a Geological History of the Earth, which was translated and inserted in the *Edinburgh New Philosophical Journal*, 1827.

"The main argument against the former extension of glaciers, has been the great change of climate which has been considered necessary to account for it. It has been usual to calculate the fall of mean temperature required in any latitude to bring the glaciers to the level of the sea, by supposing that each degree (Fahrenheit) of depression will lower the snow by about 300 feet. Consequently it is argued, to have glaciers at the level of the sea in the south of Norway, the snow-line must be lowered 5,500 feet, corresponding to some 18° of Fahrenheit—a prodigious change. But the principle is incorrect. It is on the *summer* temperature mainly that the position of the snow-line depends. It is exceedingly probable that a diminution of the temperature of the summer months by 4° only would at once place Norway within the snow-line; and so vast a mass of perpetual snow would refrigerate the climate (especially the summer temperature) to such a degree as would unquestionably pour glaciers into every fiord in Western Norway. In Iceland, in lat. 65°, snow lies at less than 3,100 feet above the sea; whilst in the same latitude in Norway the snow-line is in the interior 3,900 feet, and on the coast 3,500 feet, yet the mean temperature is about the same in each."*

It is interesting to notice the delicate balance of forces by which the existence and condition of the glaciers is regulated. If the summer temperature of the climate of the district were lowered a very few degrees, the Buerbræ glacier would continue its devastating course down the valley. On the other hand, were the average temperature raised in the same proportion, the glacier would recede year by year until it arrived at a height where it would find its equilibrium. Professor Forbes observes—"It is one result of the progress of science to show the nice adjustment upon which the stability of the existing order of events depends. The submergence of Europe to a small extent in the ocean, a divergence of the great oceanic currents, an alteration in the mean dampness of the air, would alter all the conditions of life on our continents, and clothe them with abundant snows such as we find in the southern hemisphere."

The striking evidences of glacial action which are so prominent in the valleys opening from the Hardanger Fiord, are not so palpable in those connected with another great arm of the sea, the Sogne fiord. In the valley of Laerdal, for instance, which, with the chain of lakes commencing at Nysteun and extending in the direction of the Christiania fiord, much resembles the great glen of Scotland, though glacial action is not wanting, the greater part of the phenomena point to aqueous action long continued; such as flat straths, evidently the beds of ancient lakes, rising in successive terraces one above another, with water-worn boulders, gravel, and soil along the shores.

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* "Norway and its Glaciers," p. 242.

The eastern side of the water-shed in Norway presents problems of a much more complicated character, the surface being more gentle and undulating, giving evidence of having been subject to long-continued aqueous influences and currents.

The conditions and phenomena which characterise the Norwegian valleys are manifested, on a much smaller scale, in the scenery of the Western Highlands and of North Wales. We find the *roches moutonnées* in the course of the glacier, the tearing and grinding operations at the sides, the moraines of the advancing glacier, and the lakes formed behind. In the valleys which surround Snowdon, lakes Llanberris, Gwynant, Cwellyn, Ogwen, Idwal, may be mentioned as instances. In the Western Highlands, Loch Maree, Loch Torridon, Loch Doule, and many others, exhibit the same characteristics.

I submit with deference the above observations to the Society, as a humble contribution to the illustration of a very wide subject—the influence of glacial action in moulding and shaping the surface of the globe we inhabit, and fitting it for human habitation.

Since the above pages were written, I have had the opportunity of perusing a *Memoire,* by M. C de Seue, of the University of Christiania, entitled "Le Nevé de Justedal et Les Glaciers," 1870, a copy of which has been forwarded to the Liverpool Geological Society. The views of the author on the phenomena presented, so far as they run parallel with my own observations, are so confirmatory of the views presented above, and are so interesting in themselves, that I make no apology for translating and condensing such portion of the work as is applicable to my present purpose.

The field traversed by M. de Seue, was the mountainous region to the north of the Sogne fiord, my observations having been limited to the district south and east of that great arm of the sea. This region he explored in the summers of 1867—8, and 9 successively, and has recorded a very valuable series of observations on the snow fields, the glaciers with their structure and rate of motion, their advance or recession, and on the meteorology and temperature of the district.

The great snow plateau of Justedal extends, from N.E. to S.W. 87 miles, with a width varying from 7 to 22 miles. Its average height above the sea level, is from 4550 to 5350 feet. Several of the mountain crests rise above this, the summit of the Lodalskäbe reaching the height of 6800 feet. The geological formation is principally gneiss, with mica and quartzose schists occasionally occurring.

M. de Seue made observations on twenty-four glaciers all descending from the same plateau into the different valleys around.

For many years previous to 1868, the whole of these glaciers had been receding; some of them at a very rapid rate, that of Boium for instance had receded nearly 2000 feet in 150 years, that of Tunsbergdal nearly 1000 feet in 50 years. Since 1868 nearly the whole have been advancing, some of them very rapidly, and have destroyed a large quantity of cultivated land.

I have alluded above (p. 27), to the granulated structure of the ice of the glaciers. M. de Seue made very careful observations on this subject, the results of which he gives as follows:—"The ice of the glaciers is composed of particles having crystalline form, but always distinguishable from true crystals by their facets, which are not in flat planes but bent on two sides. The mode of formation of these particles may be thus explained. The substance of the glacier ice derives its origin from the plateau of snow, which is completely crystalline in its structure. The crystals in melting become obliterated, and are converted rapidly into snow of a granulated structure, locally called *Firn.* By the pressure of the superimposed mass on the underlying portion, and the consequent friction, a certain amount of heat is developed. The melting and friction together, shape the grains of snow by rounding off the sharp angles of the crystals, which are converted into particles of irregular form. By regelation, several of these particles unite, and by their aggregation produce granules, which go on increasing by further union as the ice glides down the slope, by the progressive movement of the glacier."

"The longer the glacier is, the larger these granules become. Thus in the lower glacier of Suphelle of which the length is 2,500 metres, the granules taken from the extremity were 2 centimetres in diameter, whilst at the foot of the glacier of Tunsbergdal, which is 14,000 metres long, the granules were found to have attained a diameter of 10.5 centimetres or 1.36 English inch. The larger the granule, the more irregular is its form. The large grains are usually surrounded by smaller ones, and are scarcely ever immediately in contact with each other. When the structure is disturbed, the grains separate and fall asunder with the slightest pressure." These particulars from M de Seue, correspond in all respects with my own observations on the structure of the glacier ice.

In common with Professor Forbes and Professor Esmark, M. de Seue is of opinion that the glacial action at a remote period extended over the whole of Norway, but he makes no attempt to connect the ancient phenomena with the modern, or to account for the appearances as they now present themselves. In reference to the fiords he says, "Traces of a glacial period of a time long past are not wanting in the neighbourhood of Justedal any more than elsewhere in the country. There is, however, a certain difference in their frequency according to the elevation of the localities above the sea level. Thus distinct traces of striation present themselves very frequently on the shores of the fiords, whilst they are relatively rarer on the higher elevations. This is very striking, and cannot be merely owing to the fact that striation would more naturally be effected in the lower levels. The phenomenon is probably only apparent, an opinion which is confirmed by many circumstances. Where the abrasion is aided by vegetation it must be more destructive than on the water level where the waves are constantly laving the shores."

"It may be also, that the traces of striation are concealed by the debris strewed over the surface, and by the vegetation which has taken root in the loose material or on the solid rock. I have often observed that the striæ have been made visible by irruptions of boulders, which have swept the flanks of the mountain. The most efficient agent in wearing down the surface, and by consequence, in erasing the glacial markings, is the infiltration of water into the crevices, and the subsequent congelation. The more frequently this occurs, or what is the same thing, the oftener the temperature varies just above and below the freezing point, the more rapidly the decomposition of the rocks proceeds. The temperature of the water of the fiord, and consequently of all objects in immediate contact with it, is almost constantly, both in winter and summer, above the freezing point. The Sogne fiord and its branches are very rarely covered with ice. During the winter the temperature of the air on the low levels varies continually between plus and minus, and in the higher regions the same variation takes place all the year round. The decomposition therefore must necessarily be more active in the upper than in the lower levels, and thus the glacial markings will be more easily effaced. It is probable, however, that the lower levels have actually been more subject to glacial action than the higher ones. Not only would the pressure increase with the depth of the ice, but as the glacial current diminished, the higher levels would first lose the grinding and abraiding influence, whilst the lower levels continued to receive fresh impressions."

The direction of the markings all over the country follows the direction of the slopes in the valleys and the fiords. M. de Seue traces the existence of ancient moraines below the sea level in several parts of the Sogne fiord. Across the Fjœrlands fiord, which is a northern branch of the Sogne, there exists a bank extending from shore to shore. The Nœre fiord, which is a similar branch on the south side, has a bank of the same description, and in the Sogne fiord itself a similar bank is found extending across. But the most remarkable bank of this description is one at the mouth of the Sogne fiord, extending between the Isle of Ytre Sulen and the Isle of Kvernœ. Within this bank the depth of the water is 1225 metres, when it suddenly shoals to 213 metres, and again deepens seawards to its original depth. M. de Seue says, "It is very probable that there has here been formed an enormous moraine; the glacial current which swept down the Sogne fiord having here met with the warmer waters of the sea, would remain stationary by the melting of the ice, and the rocky materials brought down by the glacier, would thus be accumulated in a heap."

In these remarks of M. de Seue, there are two points to which it is singular so little attention is paid. The first is the *roches moutonées,* or polished and rounded surfaces along all the lower levels, which form a very prominent feature in the scenery of the fiords and valleys. These are exactly parallel with similar phenomena in Wales and Scotland, and mark the bed of rock over which the ice-stream flowed. As one of the phenomena leading to certain deductions, they are quite as important if not more so, than the marks of striation. They are alluded to, but only in a very cursory and secondary way. p. 45.

The other point is, the great changes of level as well as climate, which must have taken place since the glaciers formed their ice currents down the fiords. Many of these are of such great depth, that the ice brought down would have floated off by its lighter specific gravity in the shape of icebergs, and no abrading action could have taken place. The ice action everywhere visible, necessarily implies, that at the time it was produced the bottom of the fiords must have been above the level of the sea. In any general inferences to be drawn from the glacial phenomena of Norway, change of level is one of the prime elements to be taken into account.

Considerable notice is taken by our author of the hollows, called "Giants Cauldrons" or pot holes, as evidences of the ancient Glacial epoch, and of great changes in the surface contour.

He accounts for their formation in three ways, first, by waterfalls. It is only in very rare cases that he considers these holes produced by the vertical action of water; the forward motion of the glacier would prevent this.

Second, by currents of water. When a large fragment of rock is set in movement by the force of a torrent, it disturbs other smaller fragments with which it is surrounded, and when the debris thus set in motion is arrested by a local obstacle, it begins to turn in a circle round an axis, and by the grinding force of the sand and gravel a pot hole or giants cauldron is formed.

The third mode of their formation, is directly by the action of the ice. The glacier is seldom exactly adjusted to the form of its bed. Ordinarily it is separated by stones or rocks interspersed, which serve as rollers. When one of these stones is arrested by an obstacle which prevents its progressive movement, the motion becomes rotatory round an axis. In thus turning the stone, the glacier hollows out the rock. M. de Seue is of opinion that by far the greater number of pot holes is thus formed.

Our author has observed and noted a large number of ancient moraines, but he sets up no theory as to their relation to the modern formations, nor as to the evidences they afford of the changes the country has undergone. He says,

"The moraines of the glaciers in Justedal are ordinarily of considerable size, but this is not the case to any great extent with the terminal moraines, which may be considered as a proof of the continual oscillation of their position. Their height seldom exceeds 3 or 4 metres."

"In the neighbourhood of almost all the glaciers of any magnitude, we find a number of ancient moraines, the height of which does not exceed 4 metres. Where these moraines have disappeared, it is probable that the torrents issuing from the foot of the glaciers which are continually changing their bed, may have washed them away. The lateral moraines are in general of larger size than the terminal moraines, and reach the height of 10 metres. In respect of these it is very difficult to determine which belong to the ancient and which to the more recent formations, as the masses of the moraines *are confo*unded without any very distinct limits."

"The largest are the base moraines (*moraines profondes*). The lower end of each of the valleys which radiate from the *névé* of Justedal may be considered as a single deep moraine, which, without distinct limits, is continued to the foot of the existing glacier."

"It is not probable, so far as my observations extend, that any considerable part of the materials which constitute the moraines can have been derived from the irruption of boulders. The preponderating portion of these materials is derived, in my opinion, from the bed of the glacier. It happens that sometimes the force of the glacial mass in its motion grinds down the mountain, and the freezing of the water filtrated through the crevasses breaks off large masses of stones. Towards the end of the summer, when the glaciers are deprived of their covering of snow, and the crevasses and subterranean channels are become large and wide, the frost penetrates the glacial cascades to the base, and extends to the flanks of the mountains, freezing the water which has penetrated the crevices, which bursts from time to time. The blocks thus detached are carried down by the ice, which *en route* breaks and polishes them by contact with each other and with the mountain sides. By this operation are formed the gravel and mud with which the glacier torrents are charged. It is for the most part of the stones disengaged from the flanks of the mountains and of the gravelly materials of the crushed rock that the base moraines are composed. One part is drawn towards the edge, and serves to increase the lateral moraine; and another part, raised to the surface of the glacier, goes to augment either the lateral or terminal moraine.

"The conditions under which these moraines are met with seems to deserve special attention. In proximity with all the great glaciers we find a number of moraines, whilst the valleys are totally destitute of them for long distances; and they most frequently present to the eye the aspect of nearly horizontal plains. We conclude from this, that there has been a period during which the glaciers, being constantly in retreat, had not time to create terminal moraines, which are only formed when the extremity of the glacier remains for some time stationary or when they advance, pushing before them the detached materials which are found strewed over the bottom of the valley. After this continual retreat, a time has come during which the retrograde movement has been replaced by immobility or by progression; and it is in this way that the terminal moraines which now appear at the extremities of the glaciers have been formed."

So far as it goes, M. de Seue's opinion of the causes of the moraines is identical with my own; but he does not attempt to account for the enormous moraines which, accompanied by lakes, occur at the extremity of every fiord, which must have occurred subsequently to the existence of the fiord, but from the effects of an advancing glacier. I have endeavoured to account for them above—with what success my readers must judge.

I have also alluded above to the succession of terraces in the valley of Lœrdal, which I attributed to a series of beds of ancient lakes. M. de Seue has noticed the same phenomena, and thus remarks upon them:—

"Amongst the glacial marks I may cite the large number of terraces which are found in the valleys. They are sometimes, as in the valley of Lœrdal, of the height of 165 to 190 metres, but in general their elevation is much less. They are always found ranged one after the other at different heights, but I have not found that the height of the respective steps of one valley correspond with those of another, and the number of terraces differs in each valley. It is very probable that these terraces have been worn down by the erosive action of the glacier torrents."

According to M. de Seue, the forms of the mountains present the grandest traces of the ancient glacial epoch. The characteristic forms which are met with almost everywhere, are produced by the large number of excavations—locally called *bottener*. By *botten* are understood the cavities in the mountains which may be considered as cauldrons half-finished.

"When we observe the forms of the mountains where the glaciers precipitate themselves into the valleys, we shall see that these localities, were the icy covering removed, would offer the appearance of a depression or of a cavity in the form of a so called *botten*. Almost all the empty bottens shew by the moraines which still remain. that they have once served as the beds of glaciers. Their formation cannot be referred to the direct action of the glaciers, but no one who examines them attentively, can have any doubt that the glaciers have had much to do with their formation, especially with their rounded form. The partial melting of the glacier ice furnishes the water which penetrates the clefts of the rock, and by its congelation tears away fragments in a chaotic mass. These fragments are carried down by the advance of the glacier, and the same process is repeated. The largest and most regularly formed *bottens* are found where the rock is composed of schistose gneiss and schists, with the stratification at a high angle."

"It is probable that the formation of these bottens belongs to the latest stage of the glacial period, when the glaciers had considerably receded, a period which in these regions may be considered as still existing. It is scarcely possible to resist the conclusion that the *névé* of

Justedal is a debris of this geological epoch, though the full proof still remains to be established."

M. de Seue enters at great length into the meteorology of the district, into which I will not attempt to follow him.

It will be seen from the passages I have quoted above, that he is a careful and minute observer of phenomena; but his faculty in putting together the facts observed so as to bring out their bearing on each other, and deduce from thence general conclusions, is not so obvious.

Since this paper was written, Mr. James Geikie's exhaustive work on the "Great Ice Age" has been published. The comprehensive nature of his survey, and the wonderful results of his generalizations from the facts brought forward, render this work peculiarly valuable, though some of the questions raised still remain in doubt.

JANUARY 13TH, 1874.

THE VICE-PRESIDENT, T. MELLARD READE, C.E., F.G.S., in the Chair.

The following communication was read:—

THE CARBONIFEROUS LIMESTONE AND MILLSTONE GRIT OF THE COUNTRY AROUND LLANGOLLEN.

BY GEORGE H. MORTON, F.G.S.

The publication of this paper is unavoidably postponed.

FEBRUARY 10TH, 1874.

THE PRESIDENT, ISAAC ROBERTS, F.G.S.,
in the Chair.

The following communications were read:—

ON SOME GRAPTOLITES FROM THE UPPER ARENIG ROCKS OF RAMSEY ISLAND, ST. DAVID'S.

BY JOHN HOPKINSON, F.G.S., F.R.M.S.*

AT the meeting of the British Association at Brighton, last year, I gave an account of a number of Graptolites which had recently been found in the Arenig rocks of Ramsey Island and Whitesand Bay, near St. David's. Twenty-two species, belonging to nine genera, were then enumerated; and, both in their genera and species, these graptolite-bearing rocks seemed to be more nearly allied to the Quebec rocks of Canada than to their British representatives, the Skiddaw slates of Cumberland and the Arenig rocks of Shelve. Half the species were new; but the rest, and all the genera, were Quebec forms; while five of the genera, represented by fourteen species, were not known to occur in the Skiddaw slates, and two at least of the Skiddaw slate genera were absent. But the chief point of difference between the St. David's and the Skiddaw graptolites consisted in the great abundance of the dendroid graptolites in the St. David's beds, and their entire absence, so far as known, in the Skiddaw slates, in which the true graptolites, or Rhabdophora, alone occur. These dendroid graptolites, with the same, or nearly allied species, having been found in the lower beds of the Arenig rocks at Shelve, it was inferred that the St. David's beds were of Lower Arenig age.*

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* Read before the Geological Section of the British Association, at Bradford, September 21st, 1873.

During the present year St. David's has been visited by Messrs. Etheridge, Hicks, and Homfray, and Professor Ramsey, who have discovered, in the course of their investigations, a new series of graptolite beds on Ramsey Island. They occur as fine-grained black shales, without distinct slaty cleavage, and they have not the iron-stained appearance which is characteristic of the previously-known beds. They are faulted down in narrow bands between the masses of igneous rock which form the southern part of the island, and their relations with the graptolite beds discovered last year cannot be determined here. Black shales of a similar lithological character occur between the Lower Arenig rocks of Whitesand Bay and the Lower Llandeilo of Abereiddy Bay, but in these no fossils have yet been found. That they are most probably the equivalents of the newly-discovered graptolite beds of Ramsey Island will be seen presently. The latter have, so far, yielded only a few species of graptolites sufficiently perfect for determination. They are as follows:—

Didymograptus affinis, Nich.
D. *bifidus*, Hall.
D. *geminus*, His. sp.
D. *patulus*, Hall.
Diplograptus dentatus, Brong., sp.
(=*D.* *pristiniformis*, Hall.)
D. *mucronatus*, Hall.
Climacograptus scalaris, Linn., sp.

These species are all Arenig forms, and have all been found in the Skiddaw slates. Two (*Diplograptus mucronatus* and *Climacograptus scalaris*) pass up into the Llan-

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*Brit. Assoc. Report for 1872, Sections, p. 107. *Proc. Liverpool Geol, Soc., Session* 1872–73, p. 36.

deilo rocks; and it is remarkable that these are the only two species which have not been found in the Quebec group. The genera are all common to the Arenig and Llandeilo rocks. *Didymograptus,* which has furnished the greatest number of species, all exclusively Arenig forms, is most characteristically an Arenig genus. *Diplograptus* and *Climacograptus,* the two genera mentioned as not having been found in the previously known beds, are more characteristic of the Llandeilo rocks.

The evidence afforded by this small number of forms thus proves that these new Ramsey Island beds are of Upper Arenig age, and therefore higher than those previously known, and the evidence afforded by the graptolites is, I am informed by Dr. Hicks, confirmed by that of the other fossils associated with them. Their place in the coast section of the mainland is thus occupied by the shales (which are about 1,000 feet in thickness) previously mentioned as occurring between the Lower Arenig rocks at Whitesand Bay and the Lower Llandeilo at Abereiddy Bay, which latter is followed by beds containing a distinct set of fossils of Upper Llandeilo age; and we have therefore Lower and Upper Arenig, and Lower and Upper Llandeilo established for the first time, and at present in this locality only, as palæontologically distinct formations following each other in almost unbroken sequence.

Comparing, in conclusion, the graptolites of the Skiddaw slates of Cumberland, and the Arenig rocks of Shelve, with those of the Lower and Upper Arenig rocks of St. David's, it is seen that there is a parallel succession of species in the Shelve and Ramsey Island rocks, the Dendroidea abounding in the lower beds in each area, and the slightly diverging species of *Didymograptus,* with species of *Diplograptus* and *Climacograptus,* being found in the upper beds only; while the Skiddaw series, in which no dendroid graptolites are known to occur, seems to be more nearly related to the upper than to the lower Ramsey Island beds. The Dendroidea are, however, probably represented in the Upper Arenig rocks at St. David's, though not yet found, for this group is known to extend up to the Llandeilo beds in this area; but from the great abundance of these dendroid forms in the Lower Arenig rocks, it seems extremely improbable that these beds were deposited contemporaneously with the Skiddaw slates; while the presence in the higher beds of Skiddaw slate species only (so far as yet known) indicates a much more probable equivalency, and seems to show that the Skiddaw slates, which have hitherto been considered our oldest graptolite-bearing rocks, are of more recent age than the lowest graptoliferous rocks of St. David's.

TIDAL ACTION AS A GEOLOGICAL CAUSE.

By T. Mellard Reade, C.E., F.G.S.

The more we attempt to unravel geological mysteries, the plainer does it become that one of the first essentials to success is a full and accurate knowledge of the various phenomena of Nature now taking place around us. The history of the earth is the history of vast changes; but the principles of Nature—her *modus operandi*—though various, remain, if not absolutely fixed and immutable, yet, so far as the geological eye can penetrate, the same now as in the earliest ages to which we can trace a sedimentary deposit.

The subject of my paper is one which a close study of the Drift—the marine Boulder-clays and sands of the

N. of England—has naturally forced upon me. The denuding and transporting effects of tides have been well discussed and understood so far as our coast lines are concerned, and it is to horizontal changes of currents—created in some cases by the actual deposit of the current itself, which has again caused deflection, and like the channels of the Mersey in the Liverpool Bay, taken them through a cycle of change of greater or less duration—that the alternate attacks at special points of a coast-line are due. Prevailing winds also have their effect, and the character of the materials or rocks, hard at one point and soft at another, becomes in turn a governing cause. It is only in some few places like the West Bay of the Isle of Portland that uniformity of action and effect has prevailed for ages past; the result being the formation of that wonderful work of Nature—so imitative of art—the Chesil shingle bank.

These are phenomena well known, and which have been fully treated of by Austin, Lyell and many other observers; but my object now is of rather a different nature, which I will presently explain.

It has been well observed by Mr. Godwin Austin, in his admirable essay "On the Valley of the English Channel," that at the depth at which the action of the wind-wave ceases "the permanent influence of the tidal stream begins." It is to this permanent influence, divested of the complications produced by superficial oscillation or suface currents, that I intend addressing myself this evening. To make my reasoning understood, I must first explain, as succinctly as I can, the difference between the wind and tide-wave.

When a cork or any light body is floating in deep water, disturbed by the ordinary surface waves of equal intervals and heights, it revolves—as do also the surface particles of water—either in a vertical circle or an ellipse not very different from one, having the longer axis vertical. These waves are classed as waves of the second order, and are purely oscillatory. In the tide-wave—the wave originally produced by the action of the sun and moon—called the Free tide-wave, which is a wave of the first order, the movements of each particle of water, on the contrary, may be regarded as that of an excessively elongated ellipse, the shorter axis of which is vertical. Sir John Herschell explains very clearly that this difference in the motion of the particles of the tide-wave and the surface wave arises from the vast breadth of the tide-wave from crest to crest (usually called the length of the wave) compared to its height. He says:—

> "The breadth of the tide-wave from crest to crest, supposing all the earth to be covered, would be half the earth's circumference, or 12,500 miles, in comparison of which the depth of the sea is insignificant; and the slightest consideration suffices to show that as all the water which goes to form the elevated portion must be brought from the depressed, this can only take place by a *lateral approach of the vertical sections of the sea when the water is rising, and their recess from each other when falling*—*i.e.*, over a quadrant of the globe in either case, which is only another way of expressing an alternating forward and backward current at any given place."*

It also differs from the wind wave in the force producing it (called in the lunar theory the *tangential* element of the disturbing force), affecting every particle equally, down to the most profound depths of the ocean, while the wind forces creating the former, act only on the surface, and even in the most violent storms agitate the sea but to a trifling depth.†

Without going into more minute description, it is thus seen that the alternate advance and recess in the bottom of the ocean is the same as at the surface, if we leave friction on the bottom out of our calculation. In the free ocean, however, the total height of the tidal-wave between high and low water is but small; and Sir John Herschell observes that "a tide-wave of four feet in total height, advancing over a sea 30,000 feet deep, implies only an advance and recess of 2,800 feet, which, being spread over six hours, is nowhere very rapid."

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* "Physical Geography," p. 63.

† Ten fathoms would appear to be the limit in the seas about the British Isles.

In shallow seas it may seem strange at first sight, that the tide-wave rises higher and the horizontal current is more rapid in the inverse ratio of the depth of the water; but when we consider that the tide-wave is first generated and propagated in the open ocean, we can readily conceive that as the momentum of this vast body of water must expand itself somewhere, when the sectional area of the stream diminishes, the water must of necessity be propelled at a greater speed, and a derivative wave be created.*

Being desirous of ascertaining by calculation, the abraiding power due to Tidal action at various depths, I communicated with Sir G. B. Airy, the astronomer Royal, the greatest living authority on the theory of tides and waves, and he sent me the following lucid exposition, which I should only spoil by putting into any other language than his own:—

"The proportion of velocity of wave current at the top and at the bottom of the water, depends in a most remarkable degree on the proportion of the interval between two waves to the depth of the water. When the interval between the waves is not greater than the depth of the water, the bottom movement is insensible; when the interval between two waves is 100 times as great as the depth, the velocity at the bottom is sensibly as great as at the top. This supposes there is no friction between the water and the bottom.

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* "The principle of concentration of forces, on which these phenomena depend, (as pointed out by the late Professor Fleming, can be easily demonstrated experimentally, by placing in water an inverted funnel with its upper orifice closed—when this orifice is suddenly opened, the water will spring up in a jet higher than the level of the fluid in which it is placed. This principle is also well exemplified in a circumstance mentioned by Mr. T. Stevenson, C.E. ("Harbours," p. 48.):—"In November 1837, during a ground swell without wind, the water rose to the gilded ball on the top of the Bell Rock lantern, which is 117 feet above the rock, or 106 feet above the sea level at the time."

"But there is in sea channels such as we find them, much friction between moving water and the earth with which it is in contact; and this friction retards the speed of the bottom water, and that degree of retardation is a measure of the friction, or a measure of the rub of the water upon the ground, or a measure of the effort which the water is making to tear up the ground, and this I believe is all that could be said."

As the length of a tide-wave such as that of the Irish Sea, which is derivative, is so enormous compared to the depth of water it travels in, the theoretical movement of bottom water must be nearly equal to that at the surface. My object being to attempt a practical application of the principle enunciated, it struck me that, given the actual rate of the surface current, Beardmore's formula for surface bottom and middle velocities in streams, rivers, and tidal estuaries would apply. I wrote again to Sir G. B. Airy, to that effect. He replied as follows:—"I dare say that the formula which you give from Beardmore will do very well. There is probably some difference depending on the smoothness of the bottom, (as affected by the quality of the bottom.) When I looked on the water flowing along the exposed iron troughs of the Loch Katrine—Glasgow waterworks, I was much struck with the appearance of perfect uniformity of flow in all parts, *as well* as the eye could see."

Having now obtained a principle to work upon, by which a rough approximation could be made, the next thing was its application. I carefully consulted the sailing directions of the St. George's and English Channels, and those of the West and South-West Coasts of Ireland, with a view of extracting all the information I could, relative to the tides and the physical peculiarities and nature of the bottom. The Maps of the Irish and English Channels, prepared by Captain Beechy, and published in a reduced form in Beardmore's excellent Manual of Hydrology, and also the Charts of the British Islands, compiled from the latest Admiralty Surveys, have supplied me with much information.

On the Chart exhibited, I have marked in red lines, taken from Capt. Beechy's original paper, in the Philosophical Transactions, the set and rate of the flood stream in the Irish Channel, also the direction of the tidal currents in the English Channel, at the same instants of time as the outgoing tide in the Irish sea; and the maximum velocities at various stations in the map, all from the same source. Capt. Beechy says:—

> "An inspection of this map shows, that the tide enters the Irish Sea by two Channels, of which Carnsore Point and Pembroke are the limits of the Southern one, and Rathlin and the Mull of Kintire the boundaries of the Northern."
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> The stream in the Southern Channel has been ascertained to move simultaneously in one vast current throughout, running 6 hours nearly each way, at an average rate of from two to three knots per hour at the height of springs, increasing to four knots and upwards near the banks, and at the pitch of the headlands; its times of slack water corresponding sufficiently near for all practical purposes with the times of high and low water at Morecombe Bay, or more correctly at Fleetwood, which is twelve minutes earlier than Liverpool. The tidal stream is of course affected by the headlands, and the eastern portion passing Linney Head, rushes with great rapidity between the Smalls, Grasholm, and Milford Haven, towards the Bishops, which it passes at the rate of between four and five knots. After making the circuit of Cardigan and Carnarvon Bays, it rounds the South Stack at Holyhead, and sets towards the Skerries at a rate of upwards of four knots.

In the North Channel, the stream enters between the Mull of Kintire and Rathlin simultaneously with that passing the Tuskar into the Southern Channel, but flows in a contrary direction. It runs at the rate of three knots at springs, increasing to five knots near the Mull, and to four near Torr Head on the opposite side of the Channel. Near the Mull of Galloway the stream increases in velocity to five knots.

The meeting of the Southern and Northern tidal streams is in Morecombe Bay on the East, and off St. John's on the West.

Before commenting on the observed action of the tide on the sea bottom, let us see what would be its calculated effect in abrasion and movement of materials.

An inspection of the chart of the Irish Sea shows that the minimum velocity is actually zero off St. John's Point, and the maximum velocity opposite Kintire 505·7 feet. per minute. Centrally between the northern point of the Isle of Man and Wigtonshire the velocity is 384·3 feet; while in the southern entrance of the Irish Sea the velocity varies in the mid portions from 230 feet to 323 feet per minute. It will also be seen that all intermediate velocities are met with at various points.

Let us begin with the smallest velocity marked on the map—101·2 feet. Turning to Beardmore's Table of Surface, Middle, and Bottom Velocities, calculated from the formula $b = (\sqrt{s} - 1)^2$, where the velocity at the surface in the middle is s and that at the bottom b, we find that the bottom velocity will be 61 feet per minute. This rate of motion will disturb fine gravel. No doubt the effect will only be feeble. It will be seen that even so low a velocity is capable of carrying about and re-arranging the finer materials. For 230 feet the bottom velocity is 167·2 feet. 120 feet is put down by Beardmore as capable of disturbing rounded pebbles, and 180 feet angular stones. These data are given for the guidance of the engineer in limiting the velocities in artificial cuts to the permanent stability of the materials, and may perhaps on that account be, if anything, over-stated. For 323 feet the bottom velocity is 247 feet; and for 505 feet 409 feet, per minute.

The most complete set of experiments on the practical effect of running water were made by Mr. T. E. Blackwell, C.E., for the Government Referees on the Metropolitan Drainage plans, with the object of ascertaining what velocities are applicable to the movement of materials likely to be collected in sewers. Consulting this table, we find that a velocity of from 120 to 135 feet per minute started a piece of broken granite weighing 6·50 oz. and having a specific gravity of 2·66; while a velocity of from 180 to 195 feet carried it along, at the rate of 60 feet per minute. A boulder weighing 11·87 oz. started with a velocity of from 105 to 125 feet; and with a current of only from 165 feet to 180 feet, it was carried along at the rate of 90 feet per minute.

These experiments were made in a trough composed of elm, 60 feet long, 4 feet wide and 3 feet deep, set horizontally, and fed by a pond at 2 feet higher level, with sluices so placed as to direct a current uniformly down the trough. It is not stated, but I presume the velocities given are the average ones; which will, of course, exceed the bottom velocities, and so tell in our favour.

I think I have now given you sufficient information to show that the tidal stream is capable of effecting very considerable work on the sea bed, both in the carrying and piling up of materials, and also in abrading power. I have also shown that the stream varies in velocity at different points, being governed by the nature, depth, and width of the channel and the form of its bottom, and by the flux and reflux from neighbouring channels, if they exist. We may safely assume that wherever the sectional area of the stream is contracted, whether horizontally, by headlands, or vertically, by shoals or rock shelves, there the velocity is sure to increase. It has been shown by Mr. Godwin Austin that a shoal shows itself by ripples on the surface. Thus, "the rippling over Jones' Bank is very considerable; the shoalest part of the bank has 40 fathoms, with a surrounding sea-bed of 70." "The Little Sole Bank has like indications, even in the calmest weather; over the summits of this group there is a depth of 60 fathoms, with 100 fathoms at short distances around." This is also a proof of the bottom movement of the water, and Mr. Austin also observes: "The Boulogne fishermen sink their nets athwart the deeps at the east end of the Channel; should the weather become too rough to allow them to get them in, they are sure to recover them on the coast between Cape Griz Nez and Calais, whither the flood-tide drifts them."

Mr. Godwin Austin has also attempted to show, in the paper before referred to, that the coarser materials are found inshore, and the further out we go into the offing, the finer the materials composing the sea bed become. I do not, however, think that this statement can be supported as a wide generalisation, and he himself has to struggle against many exceptions. It appears as if though stating correctly the tidal theory, he insufficiently appreciated the mechanical force of the tides. Applied to a lake, or to an almost tideless sea, like the Mediterranean, the theory he propounds is, no doubt, consonant with facts.

NATURE OF THE BOTTOMS OF THE IRISH SEA AND ENGLISH CHANNEL.

The late Capt. White, R.N., gives the following general sailing directions in approaching the south-west coast of Ireland and the Bristol Channel from the Atlantic:—

> "When running in from the Atlantic Ocean for the purpose of rounding Cape Clear, the quality of the ground is of much greater con-

sequence than the depth; for so long as the ingredients brought up by the lead remain free from oozy matter, you cannot be nearer than 6 leagues (9 geographical miles) from any part of the Irish coast between the Skelligs and Browhead, let the depth be what it may, but may be considerably farther from it. On the other hand, if oozy ground be obtained, in any depth of water between 62 and 92 fathoms, you may be sure you are within that distance, and consequently northward of the latitude 51° 10′; for were you southward of that parallel, the ground between those limited depths would be totally free from ooze until you had advanced as far eastward as the meridian of Cape Clear." *

Between the 100 fathom line west of the Little Sole Bank and a line drawn between Ushant and the Land's End, the soundings are nearly all sand or sand and shells. This is practically the entrance of the English Channel. Between the Great Sole Bank and latitude 51° 10″ it is the same. But the great central area from the Great Sole Bank to the Bristol Channel and between the Land's End and the south coast of Ireland is occupied by mud and ooze. In the Irish Sea, between St. David's Head and Bardsey Island in Carnarvon Bay the bottom is mostly sand, or mud, sand, and shells, with or without stones. Off Holyhead there is mud, sand, and shingle; from thence round to the Liverpool Bay it is sand and shells, and in the estuaries of the Dee and Mersey ooze and silt. Midway between the Isle of Man and the Great Orme's Head, and from thence to Morecambe Bay, is mud and sand; while in the area of no-current between the Isle of Man and Ireland is a deposit of fine blue mud. The patches of blue on the chart represent shingle or stones, as do also the spots marked with a blue ring. Comprehensively speaking, it is difficult to draw a distinction between the character of the bottom of the Irish Sea in the course of the stream tide from the entrance between Tuscar and St. David's Head. Sand alternates

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* "Sailing Directions for the West and South-West Coasts of Ireland," p. 80.

with mud, shells, sand, and gravel; mud, sand, and stones; mud, sand, and shells; and mud, sand, shells and stones; and these changes seem to occur without much reference to depth. On the east coast of Ireland, between Tuskar and the Codling Banks, sand and shells, with or without stones, seem to preponderate; while the bottom of Cardigan Bay seems to retain the general character of the main channel. At the head of the stream there is a preponderance of mud and ooze, and this applies generally to the bottom off the Lancashire coast. Skirting the stream on the west, between Lambay Island and the Calf of Man, the mud preponderates, gradually developing into pure mud as the central area of "*no-stream*" is approached. Between this area and Ardglas Bay, sand, sand and shells, and mud, sand, and shells, are found.

In the North Channel, from a line drawn between Cathair Point, in Islay, and a point a little south of the Mull of Kintire, the bottom is nearly all sand, shells, and gravel, the whole way across to the North of Ireland. The Firth of Clyde is mostly mud; the North stream tide, for the remainder of its distance until it meets the Southern stream, seems to have the same character of bottom as that which I have described the Southern stream as travelling over. This character of bottom seems to occur without reference to depth. Off St. Bee's Head there is mud and ooze. The Solway Firth is nearly all mud and sand.

Such is the character of the Irish sea bottom. If, on the other hand, we turn to the English Channel, we find it is of a much clearer description, being nearly all sand, fine gravel, and shingle, with or without shells.

Before investigating the relation, if any, which the depths bear to the tidal currents, as modified and governed by the original form of the bottom before submergence, can we from the few facts I have mentioned draw any legitimate inferences? I think we may. I have shown, theoretically, that the stream tide is capable of moving even shingle; and, if the force acted constantly only in one direction, its effects would be most destructive; but this it does not do. The stream travels backwards and forwards, oscillating like a great pendulum; and it cannot deal with any matter excepting what is brought into it by rivers, what it erodes from the coast, or what it finds on the bottom itself. I have no doubt that the mud of the Irish Sea is principally re-distributed and re-composed Drift matter. The whole of the land on either side, comprising drainage areas of great extent, all delivering into the Irish Sea, is wrapped over with the clays and sands of the Glacial period, and doubtless the Irish Sea bottom was also thus covered, and has since been re-covered by Post-glacial Deposits of the period, represented by the Formby and Leasowe Marine Beds.* The rivers and the sea have, comparatively speaking, little to act upon except this Drift. If, again, we turn to the Frith of Clyde, we see the bottom is nearly all mud. The cause, again, is obvious: it is derived from those classic beds of silt and laminated clay which have made the Clyde geologically famous.

In the Sound of Islay the same phenomena occurs; and it is only when we get outside into the Atlantic that we get free from mud. The tides, and the winds assisting them, coming in from the pure ocean uncharged with mud, push up the sands, shells, and gravels resting upon the submerged plateau between the 100-fathom line and the land as far as and beyond the Mull of Kintire.

In the English Channel, on the other hand, the rivers draining into it are of little moment, and the land is not of the nature to produce so much mud. South of a line between Bristol and London, there is no Drift of any consequence to be met with. It is true there are the clays of the Lias, a patch of Red marl in Dorsetshire, the Kimmeridge clays and the chalk cliffs, to yield materials for mud-making; but these cannot compare in extent or capacity with the Northern Drift. Again, those who have seen the coast of Dorsetshire and the Chesil Bank will appreciate the sand-making capacities of the tides and winds acting upon the coast from the Land's End to the Bill of Portland, where a mass of silicious shingle is ever travelling backwards and forwards, but mostly Eastwards, and getting ground down into the finest gravel and coarse sand. It is to these causes, I am convinced, we must look for the difference in the nature of the bottoms of the two channels.

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* See my "Post-glacial Geology of Lancashire and Cheshire."—*Proceedings of Liverpool Geological Society*, Session 1871–72.

We have now seen that the materials of the bottoms may be grouped in classes, and that within these large groups the sea sorts and arranges its materials as it does on the beach, into sand, mud, shells, gravel, shingle, &c.; and, though to determine in detail why sand is here or gravel there, would be too complicated a mechanical problem to enter upon, yet, broadly speaking, we must recognise that the materials of the bottom are in exact equilibrium with the moving forces. The tidal movement is oscillatory, and varies in intensity and direction both in the ebb and flood. If we could imagine a tide of equal intensity and of equal time as to ebb and flood acting in parallel lines—a practical impossibility—the materials of the sea bottom (assuming the particles to be of the same size, form, and specific gravity, and the bottom a perfect plane) would also arrange themselves in parallel lines. The moment, however, we introduce the slightest deviation from these conditions, variations in the resistances at different points are caused. These, again, by the piling up of materials, in certain localities cause deflections of the current, which again react on other portions of the bottom; and so on, *ad infinitum.* If to these causes of variation we add originally unequal bottom, irregular coast line, headlands, and river estuaries, and the different rates as well as direction of the tidal stream caused by them, we may easily conceive why the sea sorts its materials in the way it does. We must not, however, lose sight of the great fact that, though the ebb and flood are not quite of equal duration in the Irish Sea, yet the materials travel backwards and forwards over the same area. Though this is the case, it is easy to see that if either the ebb or flood preponderates constantly by ever so small an increment, the tendency will be to push the materials in one direction. Again, if the bottom of the channel rises in a regular gradient, say to the head of the tide, the materials of that channel must tend to work downwards by gravitation, even if the forces of ebb and flood be exactly balanced. The rivers pouring their quota of water into the sea making the ebb preponderate, be it to ever so small an extent, must also act in the same direction; while the prevailing winds, by producing an additional head of tide, must also have their effect. It is a well-known fact, also, that shells are strewed over the sea bottom which have come from the littoral zone;* and unless a *progressive* motion were imparted to them, in addition to the oscillatory one, this could not happen. Therefore, in my opinion, the tides perform the great function of distributing the materials that come within their grasp over great areas of the ocean floor. On any other supposition it is impossible to account for the sand and shells, and also gravel and stones, found at great depths off the 100-fathom line on the west coast of Ireland; for, even assuming them to have been in the same position since submergence — a supposition for which there are no grounds — the mud with which the ocean is to a certain extent charged, as shown by extensive deposits over portions of the Atlantic, must be prevented by currents of some kind from deposition, or else they would get covered over. Thus in the line of the French Cable in Latitude 47° N., the soundings showed sand, mud, and small shells, pretty nearly the whole way across the Atlantic, and at depths reaching to 2,460 fathoms. If there were no currents capable of moving sand, the whole would be evidently covered up with fine mud, and if there were no currents capable of moving mud, there would be nothing but pure carbonate of lime extracted from the water, by *Foraminifera* and other organisms.

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* Mr. Godwin Austin mentions the *Haliotis tuberculata* as occurring 50 miles away from any spot where it could have lived.

FORM OF THE BOTTOM IN RELATION TO TIDAL CURRENTS.

Areas of Erosion.—I have shewn in my "Post-glacial Geology of Lancashire and Cheshire," that within the depths of from 6 to 8 fathoms in the Liverpool Bay, and also on the littoral zone, there are areas of denudation and areas of deposition, and that these areas are not constant, but inter-changeable, so that, what was once an area of deposition may by change of currents become an area of denudation, and *vice versa.* In the Mersey estuary, excepting on the littoral zone, I know of only one locality, situated in the Crosby Channel, where the actual clay of the Drift is bare, so that practically at the Mouth of the Mersey, and as is the case in all similar estuaries, the principal work done by the tides, is the pushing about and re-arranging of the recent sands and silt. It is now my purpose to extend the observations to greater depths, and the following are some of the examples upon which I rely:—

Mr. Thomas Jamieson, F.R.S., in his excellent paper on the "Last Changes in Scotland,*" says, that Mr. Robert Dawson, of Cruden, who has explored the Malacology of the Aberdeenshire Coast with great success, tells him that when dredging, he finds a great many semi-fossil Arctic Shells, belonging to a species which he never meets with alive. These he supposes to be derived from Glacial beds passing underneath the sea, and extending for a considerable distance out from the Coast. In Mr. Dawson's own words—

> "All the fossils included in the list were dredged by me off the Coast of Cruden and Stains, at a distance of from three to eight miles from land, and at a depth of from thirty to forty-five fathoms. As however, some of them (*Trophon Scalariformis* and *Gunneri*, *Pecten Islandicus*, &c.,) have been brought up by the fishermen's lines at the distance of thirty miles from land, I believe the fossil-deposit, whatever it may be, extends to a greater distance seawards. The reason why they are not found nearer the land appears evidently to be, that the sea-bottom for at least three miles from shore, consists of fine sand, covering probably the fossil-deposit beneath. None of these species have been found by me *alive*; and from the appearance of all the specimens, I believe that none of them are alive in the district."

Dr. W. King says, in *The Geologist*, vol. vi., p. 169, "When dredging in 50 fathoms on the West-side of the Dogger Bank, off the Coast of Durham, the Dredge brought up a large quantity of dead specimens of *Mya truncata* in a chalky condition," and infers the bed to be a Glacial or a Post-glacial, and not a recent deposit.

Again, the Sailing directions for the North Coast of Ireland says p. 81, the Channel between Irishtraull Island and Garvan Island, "has from 20 to 40 fathoms in it, with the streams of tide setting directly through." "*The velocity of the tides has swept away all the loose soil, and left an irregular bottom at the above depths.*"

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* "Quarterly Journal of Geological Society," 1865, p. 200.

A reference to the Chart of the West Coast of Ireland shews, Leck rock off Dursey Head bare at 40 fathoms, and Edye rock, situated further South, bare at 43 fathoms. These rocks appear to be surrounded with water of from 50 to 70 fathoms.

Between Dunmore Head and Loop Head, in a space extending a degree West of the coast, are no less than nine soundings, showing rock at the bottom in depths ranging, from 40 to 77 fathoms.

Kerry Head Shoal from fourteen to twenty fathoms is an uneven rocky bottom.

Between Loop Head and Skird rocks off Galway Bay, there are seven soundings, showing rock at depths of from 38 to 53 fathoms.

Outside of the one hundred fathom contour, and North-west of Broadhaven Bay, there is a sounding, showing rock at 146 fathoms, and North of this again, rock and shells at 115 fathoms.

From Broadhaven Bay round the North Coast to Malin Head there are no less than sixteen soundings given as rock, at depths ranging from 36 to 64 fathoms.

These are some of the examples we have before us to reason upon, and if similar observations were made in other seas and on other coasts, no doubt they could be considerably extended. We are I believe justified in drawing the following conclusions:—

First—That in all probability many of these spots have been originally covered with drift or other deposits, which have been swept away; but as we know there have been oscillations of level, it is impossible to say when or at what depths this has occurred. We must bear in mind that, with the exception of Leck and Edye rocks, the rocky soundings given are not projecting prominences, but are surrounded by water of the same, or about the same, depths. It must not be forgotten that these soundings are the records of very careful observations, made for the guidance of mariners, who, in thick weather, when for days they may have to navigate without the possibility of astronomical observation, are dependent on the nature of the bottom, taken together with the depth, for the power of groping their way, figuratively speaking, in the dark. Granting also that there may possibly be some difficulty in distinguishing a hard bottom of any kind, by soundings, from actual rock, it is quite sufficient for my purpose that it is a hard bottom; for in that case, except in very exceptional instances, it is not a recent deposit. There is this circumstance also to be considered—that, were there only little bottom movement, a deposit of mud would surely take place; and if we turn to a tideless sea, such as the Mediterranean, we find it distinguished by a fine muddy bottom, which peculiarity, Dr. Carpenter says, accounts for the barren result of his dredging in that sea, the fine impalpable mud being unfavourable to animal life; and I think we might add, the want of that interchange of water which daily takes place, even in the open ocean, from tidal causes. We know that in the area of "no-tide-stream" in the Irish Sea there is nothing but fine mud, we know also that in the Irish Sea we find mud here, sand there; in one place stones, in another shells. We know also that this sea is receiving daily contributions of mud from the many rivers flowing through countries covered with drift-clay, and we see that these materials are assorted and distributed in a certain orderly way over the sea bottom. If, then, we have a right to infer a peculiar set of currents, or combination of currents, which accounts for this *non*-deposition of material in certain areas, may we not also legitimately infer that in some of these areas the tidal currents being a little stronger, may even erode the bottom in the open ocean—as, for instance, off the west coast of Ireland, or off Cornwall, in the English Channel, where in a place quite near enough to receive mud deposits from the Irish Sea, there is rocky bottom at 40 fathoms. It is also evident that in the German Ocean, full of moving sands and other deposits of a recent character, the beds of drift are, in places, bare and eroded. These observations are none the less, but rather more valuable, inasmuch as they were not made for the purpose of supporting any theory, but are a body of facts carefully collected by practical men for practical purposes only. When we find by theory—the result of calculation from observed facts—that the tidal stream at very great depths should be able to move considerable masses of material, and when, on consulting practical observations made for other purposes, we find that such materials must have been moved, and when we know that the disturbance due to wind-waves reaches down but to inconsiderable depths, there is (unless we take refuge in the absurdity that the bottom of the sea is in just the same condition as when it first subsided) no other explanation left us than that the cause, primarily, of the arrangement of materials composing the sea bottom, except in the profoundest depths, is tidal action. I have quoted from practical mariners to show that the tidal currents in certain places have swept away the loose material of the bottom. It is also extremely probable that, from the nature of the coasts, channels, and set of the stream, that confluent streams unite and produce a bottom velocity greater than that at the surface. It is also probable that, as the stream tide is in some places not constant in direction, and that the ebb either does not traverse the same area or crosses it at a different angle, erosion in one place and deposition in another is the result. It is also a well-known fact that in some places the ebb tide lasts greatly longer than the flood. In making for the English Channel, vessels coming from the southward, in consequence of the tide running nine hours to the northward and only three to the southward, frequently fall into the Bristol Channel. This is caused by the flood tide exceeding the ebb; but flood and ebb are only relative terms, for what is ebb in one place makes flood in another. This unequal stream begins about 14 leagues west from Scilly. It first runs N.N.W., and continues to alter till it comes to the E.N.E.; the flood tide then ceases to run.

Time tells me I must bring my remarks to a close, or I could have given many more examples. There is, however, a remarkable phenomenon which I have reserved for the last. Capt. Beechy says:—Speaking of the tide entering the North Channel. "The *main body* sweeps to S. by E., taking nearly the general direction of the channel, but pressing more heavily on the Wigtonshire Coast; *off which it has scooped out a remarkable ditch, upwards of* 20 *miles long by about a mile only in width, in which the depth is from* 400 *to* 600 *feet greater than that of the general level of the bottom about it.*" This be it understood, has taken place at a maximum depth of 146 fathoms or 876 feet, a convincing proof, of what in special circumstances the tide is capable of effecting.

Again, in the English Channel there is a similar excavation on a smaller scale as regards depth, called Hurd's deep. It extends E.N.E. and E.S. eastwards, 10 leagues or 30 miles, and then takes a turn rather suddenly to the N.N.E. more than 2 leagues, and is more than 2 miles wide, being of a serpentine shape. The greatest depths are 95, 92, and 72 fathoms, coarse gravel, and 62, 54, and at its extremity 50 fathoms all coarse gravel. The surrounding bottom being from 30 to 40 fathoms. This deep is an excellent guide to mariners groping for their whereabouts. To the South-westward of this is the west deep about 11 leagues in extent E. and W., and from 2 to 3 leagues in breadth, having from 37 to 45 fathoms.

Further up the Channel is the North deep, extending from abreast Christ Church Head to above Brighton, at a distance of from 5 to 6 leagues from the coast. It is of various breadths, from 2 to 5 leagues, and has throughout coarse gravel, with from 4 to 10 fathoms greater depth than will be found between it and the land.

The bottom of the North Channel Gulley before referred to, is composed of mud and shells, sand, and sand and shells, and is in fact similar in nature to the bottom surrounding it. The bottom of the English Channel is of a coarser nature than that of the Irish Sea, particularly off the coast of France. This is only another proof, that the sea deals only with the materials placed immediately within its grasp. If we imagine a valley the width of our Mersey at Egremont, and seven times deeper than it is at the deepest part, measuring from the level of the Pier Head to the bottom, we shall get a good idea of the North Sea Gulley. We cannot of course positively affirm, that the whole of this has been excavated by the tide; but it is a remarkable fact, that its longer axis corresponds precisely with the lines of stream tide given by Capt. Beechy, and if not entirely excavated, it certainly must be kept open by the current. The Hurd Deep also corresponds with the direction of the English Channel, though its Western end, is crossed by the tide from the Gulf of St. Malo—The West Deep also follows the same rule—The North Deep is much shallower and more irregular, being near the head of the tide in the English Channel. Roughly speaking the bottom contours of the Irish Sea also follow the direction of stream tide, so that without being able to affirm how many feet of material the tide has eroded here, or deposited there, is it not pretty evident a full consideration of all these facts collected from such diverse sources, shews that Tidal Action has a good deal to do with shaping the bottom of the sea?

Shoals and Banks.—If material is planed away from one place, it must be deposited somewhere else; hence the origin of banks and shoals. I have only time now to briefly allude to these; but if we cast our eye on the chart we shall see that those dangerous banks on the east coast of Ireland follow the same rule, and the Blackwater, Arklow, and Kish Banks take, in their longer axes, the direction of the stream tide. The shoals in the Straits of Dover also take the direction of the channel, as shown in the Vergoyer, Bassurelle, Ridge, and Varne Banks. Over these shoals the tide flows very fast, showing that the current brings the material by a combination of causes to these spots; and, by heaping them in its course, actually quickens the flow at certain times of the tide. Some shoals are doubtless only the original form of the land; and Mr. Godwin Austen gives very good reasons for inferring this to be the case with the Little Sole and some other banks. In the sea bottom there are also doubtless wide areas of deposition keeping a tolerably uniform level, and it is also not to be forgotten that in the area of "no stream" in the Irish Sea there is deep water, showing pretty clearly that the thickness of a deposit must necessarily increase but slowly where only very fine particles are transferred from other areas to it.

I must now conclude, with apologies for the imperfection of my sketch. The subject is, so far as my knowledge of what has been written on Physical Geology, a new one. It has, however, I am convinced, very wide and important bearings, and supplies us with a means of accounting for the very curious stratification, cross laminations, and bedding to be found in most sections of the marine Boulder-clay of the neighbourhood. I confess they were a puzzle to me (and I have drawn many sections of them, which at a future time I hope to have the pleasure of showing you) until a combination of evidences, all pointing in one direction, caused me to follow out the investigations which you have patiently listened to this evening.

MARCH 10TH, 1874.

THE PRESIDENT, ISAAC ROBERTS, F.G.S.,

in the Chair.

Mr. T. MELLARD READE, C.E., F.G.S., described an Ice-marked surface on the Keuper Sandstone, in a field opposite the Police Station, Crosby. The direction of the Striæ 40° W. of N.

The following communications were read:—

THE METAMORPHIC ROCKS OF THE MALVERN RANGE, AND THE STRATA DERIVED FROM THEM.

BY CHARLES RICKETTS, M.D., F.G.S.

The first portion of this communication was chiefly directed to the consideration of evidences of stratification in the metamorphic rocks, which constitute the Malvern range of hills, and was illustrated by sketches and rock-specimens. (Reference is directed to a paper "On the

Geological Structure of the Malvern Hills, &c," by Harvey B. Holl, M.D., F.G.S.—*Quart. Journ. Geol. Soc.*, Vol. xxi., page 72.)

It was then shown that the present contour of these hills is not dependent upon the denudation which has occurred during any one geological period, but that they have been subjected to erosion at various times and at distant intervals, whenever they have been raised above the sea-level, and the strata which had been deposited over them has been removed by sub-aërial or other causes; for disintegrated fragments derived from them constitute a large portion of the strata forming the base of those deposits, which characterize the several geological formations.

The earliest example of these fragments has been noticed both by Professor Phillips* and by Dr. Holl as a conglomerate of rounded pebbles of quartz, felspar, &c., and small particles derived from the neighbouring hills, occurring at the foot of Ragged-stone Hill, in the base of the Hollybush Sandstone, referred by Dr. Holl to Upper Cambrian. Rounded pebbles of the granitic rock may also be occasionally found in the quarry, near the entrance to the Hollybush Pass, at about a quarter of a mile's distance from the granite.

The next occurs in the shore deposit of the Upper Silurian formation, named Upper Llandovery by Sir R. I. Murchison, but which would be more correctly called Wenlock grit, sandstone, or conglomerate, as was suggested by Professor Sedgwick, when he first recognized its true relationship in the Upper Silurian series, and stated that these fossiliferous strata "might with perfect propriety" be so named, even at the time he designated them May Hill Sandstone; for they are simply a deposit in Upper Silurian or Wenlock seas, occurring along the then line of coast, the greater portion of the materials entering into their composition being derived from the neighbouring shore margins. This formation, therefore, may have been occurring at one place, whilst a similar deposit in another, which from subsidence had become situated farther from the land, would have had in progress the deposition over it of limestones and shales; these, the deposits in deeper water, called respectively Woolhope Limestone and Wenlock Shales and Limestone, are *débris* derived from atmospheric action on inland surfaces, that is, from valley denudation, which has been brought down by a *Wenlock* river.

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* "Geology of the Malvern Hills; Memoirs of the Geological Survey." Vol. ii., page 52.

On the western side of the Worcestershire Beacon, a conglomerate, consisting of pebbles derived from the hill and full of Upper Silurian fossils, was discovered by Miss Phillips, during the time her brother, Professor Phillips, was engaged in the survey of the district. The only exposure, which now shews this conglomerate abutting against the granite mass, is situated somewhat north of the place where it was originally observed, and has resulted from a landslip. But fragments, often containing fossils, can be readily found by looking over the heaps of stones which have been removed from the neighbouring fields. In the specimens presented to me by Dr. Grindrod of Malvern, and by a gentleman resident near the spot, some of the pebbles are rounded, but most of them are angular, and the contained organisms present no evidence of attrition. It may be presumed that, at the time of their deposition, the Worcestershire Beacon formed a headland, whose precipitous cliffs passed into water, of a depth so considerable, that these deposits were not much exposed to the influence of currents or of wave-action, It was under greatly different conditions that the strata, exposed in a quarry, a mile due east of Eastnor, were deposited. They consist of coarse sandstones and grits, and some of the beds may even be designated as a conglomerate, composed of small rounded fragments chiefly derived from the granite, and so far as I observed they do not contain fossils. As the particles are coarse, whilst the distance to the nearest locality, from which they could by any possibility have been derived, is at least a mile, it must be inferred that they have been deposited in somewhat shallow water, where there existed considerable tidal or other currents.

Subsequently to the deposition of the rest of the Upper Silurian series, of the Old Red Sandstone and probably of the Carboniferous rocks, these strata have been subjected to the application of a power, which, inducing excessive squeezing, has caused most remarkable folds.* This pressure has been so great that along the northern half of the range the strata are nearly perpendicular, so that the width of the denuded edges of the Upper Silurian formation but slightly exceeds its thickness.

Denudation of these contorted rocks, to the whole extent of the thickness represented by that of the different formations, took place prior to the deposition of the strata which are seen at the south-western extremity; for they lie upon the upturned and eroded edges of the Hollybush Sandstone, and of the Upper Silurian and Old Red Sandstone formations. They form a stratified conglomerate of angular, sub-angular, and a few somewhat rounded pebbles of various sizes; many being of Porphyry and other hard rocks, but some have certainly been derived from the Granite. These strata, named Haffield Conglomerate, by Phillips, are marked as Permian on the Survey maps, and form the base of the New Red Sandstone series. Whatever may have been the circumstances under which their formation has taken place, it is evident the contained pebbles have not been exposed to attrition by tidal action.

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* For a probable cause of Contortions of Strata see—"The President's Address; Proceedings of the Liverpool Geological Society for the Session 1872-73," page 26; also an abstract of the same; "Fissures, Faults, Contortions and Slaty Cleavage," *Geological Magazine*," vol. x., page 202.

The last example of these derivative rocks is that which is at present in progress. The succession of frost and thaw, of moisture and dryness, as well as, to some extent, chemical action, is disintegrating the surface of these metamorphic rocks, and the particles, being washed downwards by rains, form an accumulation of *dêbris* along the flanks, its extent being greater on the eastern side, where the area of the watershed is greater. Even at a considerable distance from the hills this *dêbris* consists of fragments of partially decomposed rock derived from them, irregularly massed together, the insterstices being fitted up with a matrix of dark ferruginous clay.

Whatever may have been done by glacial action towards the sculpturing of these hills, there is no evidence, that I am aware of, existing in the immediate neighbourhood; nor is it likely that any such would be found, unless it be that masses of the rock may occur in distant places to which they could only have been conveyed by glaciers, for, as the Malverns are exposed to the solar rays from sunrise to sunset, and there are no deep gorges in which snow could accumulate, glaciers would have ceased to exist here, long before they had done so amongst the mountains of North Wales.

During none of the periods which have been referred to has the width of the Malverns on its western flank been very much greater than at present, the division of the watershed being in all very nearly in the same place at which it is now.

In what is now the valley of White-leaved Oak, and also, but in a less degree, at Hollybush Pass, the Hollybush Sandstone extends into indentations in the granitic rock, indicating the previous existence of gorges or valleys which commenced at these places, and which became filled up as the accumulation in the neighbouring seas by its weight caused subsidence of the sea-bottom, and, with it, these neighbouring land surfaces also sank below the sea level.* But there is evidence that at this distant era the eastern flanks of these hills had also undergone denudation; for the Rev. W. S. Symonds, F.G.S., observes that at White-leaved Oak "a saddle of the Hollybush Sandstone overlaps each side of the hill,"† and, therefore, the division of the watershed must have been the same there as it is at present. Other evidence to the same effect is the existence of those sedimentary rocks, altered by the intrusion of Trap, which are situated S.E. of the Herefordshire Beacon. These have, and with great probability, been referred by Dr. Holl to the same age as the Hollybush Sandstone; but, whether correctly so or not, their presence indicates a previous denudation along the eastern side of the ridge.

It has already been shewn that, before and during the deposition of the Upper Silurian strata, denudation was taking place along the western side of the range, and that fragments of the Granite rock entered largely into the composition of the beds. There is also a small area of Upper Llandovery Sandstone, situated on the east side, but separated from that on the west by Swinyards Hill; it is also bounded on the south by the northern extremity of Midsummer Hill, and on the north-east by the southern extension of the Herefordshire Beacon and the altered Hollybush Sandstone, the Malvern fault cutting it off along the east. It is therefore situated in what had previously formed the commencement of a valley, the head of which was situated at Silurian Pass, where these Upper Silurian strata are separated from those on the west by a very narrow division only; judging from the contour of the basin containing this sandstone, the stream, which had its origin in this pre-Wenlock valley, must have taken a south-eastern direction, and it would have been a physical impossibility for its water to have emptied itself into the sea on the west of the range, without passing round one or other of its extremities. The Malvern Range must therefore, during the period when the Upper Llandovery rocks, now exposed, were in process of deposition, have formed a peninsula, or probably an island, and, at a later period, as subsidence progressed, a group of islands.

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* See "The President's Address; Proceedings of the Liverpool Geological Society for the Session 1871-72," page 23. Also, "On Subsidence as the Effect of Accumulation."—*Geological Magazine*, Vol. ix., page 119.

† "Records of the Rocks," page 34.

The breccia on the western flank at the extreme south is the only evidence which remains of denudation taking place during the New Red Sandstone period. It may be considered as certain that the same occurred on the eastern also, but the Malvern Fault has thrown down the Trias, so that its base is situated on a level, relative to the hill, far below that at which it was originally deposited, whilst that portion which, on the occurrence of the fault remained upon its flank, has been subsequently removed by denudation.*

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* A Permian breccia occurs at intervals in several small areas, along the extension of the Fault northwards, beyond the Malverns, and is considered by Professor Ramsay to have been contemporaneous with the Haffield Conglomerate. "On the Permian Breccia of Shropshire, Worcestershire &c., by A. C. Ramsay, F.R.S., F.G.S." *Quart. Journ. Geol. Soc.*, vol. xi., page 185.

The agencies at present in action have given the last touches in the sculpturing of these hills. Whenever the strata are raised above the sea-level, the great atmospheric 'chisel' is brought into operation, removing with comparative facility the unaltered sedimentary rocks, but with great difficulty the unyielding Granite; still, as opportunity is afforded, its efforts are persistent, continuing in one era that which has been accomplished in another; but leaving in the groovings that it makes, and in the 'chips' which it removes, a record of the progress that has been effected in each period of time.

THE CARBONIFEROUS LIMESTONE OF HAFOD-Y-CALCH, NEAR CORWEN.

By George H. Morton, F.G.S.

The publication of this paper is unavoidably postponed.

NOTE.

In consequence of the numerous errata in the first impression of Mr. Marrat's Paper on "Calamites and their Alliances," Session 14th, 1872-3, p. 34, a corrected edition is now given.

CALAMITES AND THEIR ALLIANCES.

BY FREDERICK P. MARRAT.

A CONTINUATION

OF A PAPER ON THE FOSSIL PLANTS, IN THE LIVERPOOL FREE PUBLIC MUSEUM, COLLECTED BY THE REV. H. H. HIGGINS, AND KNOWN AS THE RAVENHEAD COLLECTION.

A. CALAMITEÆ, *Brongt.*

1 CALAMITES SUCKOWII, *Brongt.*

var. undulatus, *Sternb.*

var. ramosus, *Brongt.*

Branches and foliage, ASTEROPHYLLITES FOLIOSUS, *Lindl.*

2 CALAMITES DUBIUS, *Artis.*, tab. 13, *Brongt.*, tab. 18, f. 1—3.

3 CALAMITES APPROXIMATUS, *Schloth*, *Brongt.*, tab. 15, f. 7, 8. *Lindl.* and *Hutt.*, tab. 77.

A very fine series of specimens, exhibiting a large amount of variation.

4 CALAMITIES CANNÆFORMIS, *Schloth*, tab. 21. *Lindl.* and *Hutt.*, tab. 78, 79.

var. DECORATUS, *Brongt.*, tab. 14, f. 1—5.

var. NODOSUS, *Lindl.* and *Hutt.*, with its branches and leaves.

var. STEINHAUERI, *Brongt.*, tab. 18, f. 4.

SPECIES DUBLÆ.

5 CALAMITES LINDLEYI., *Sternb.*, MOUGEOTII, *Lindl.* and *Hutt.*, tab. 22.

B. RAMI ET RAMULI FOLIOSI.

CALAMOCLADIUS, *Sch.*

6 Calamocladius (Calamites) longifolius, *Brongt.*

Asterophyllites, *Brongt.*, *Lindl.* and *Hutt.*, tab. 18.

Ast. comoso and jubata, *Lindl.* and *Hutt.*, tab. 108—133.

7 Cal. (?) rigidus, *Geinitz.*

Asterophyllites rigida, *Brongt*, p. 159, *Lindl.* and *Hutt.*, vol. 3, tab. 211.

8 Cal. (?) equisetiformis, *Schloth.*

Asterophyllites equisetiformis, *Brongt.*, Prod. p. 159, *Lindl.* and *Hutt.*, tab. 191.

9 Calamocladius (Calamites) grandis, *Stern.*, *Lindl.* and *Hutt.*, tab. 19. A portion of the stem.

Calamites nodosus. *Lindl.* and *Hutt.*, tab. 15 and 16.

10 Calamocladius (Calamites) foliosus, *Lindl.* and *Hutt.*, tab. 25.

Asterophyllites. (?)

11 Calamocladius (Calamites) tenuis, *Marrat*, Figured in the Proceedings of the Liverpool Naturalist's Field Club for 1870-1.

BORNIA, *F. A. Roem.*

Bornia radiata, *Brongt*, tab. 26, f. 1, 2.

SPHENOPHYLLUM, *Brongt.*

12 Sphenophyllum emarginatum, *Brongt.*

Schlotheimii, *Lindl.* and *Hutt.*, tab 27.

13 Sphenophyllum erosum, *Lindl.* and *Hutt.*, tab. 13.

var. B. saxifragæfolium, *Schimp.*, tab. 25, f. 10—14.

ANNULARIA, *Brongt.*

14 Annularia longifolia, *Brongt.*

Asterophyllites equisetiformis, *Lindl.* and *Hutt.*, tab. 124. *Schimp.*, tab. 26, f. 2.

var. tuberculata, *Lindl.* and *Hutt.*, tab. 14, (fruit);

15 Annularia radiata, *Brongt.*

Asterophyllites galioides, *Lind.* and *Hutt.*, tab. 25, f. 2.

Annularia. (?)

Asterophyllites acicularis, *Dawson.* *Quarterly Journal*, Geological Society, tab. 13, f. 16.

16 Annularia Dawsonii, *Sch.*

latifolia, (?) *Dawson.* *Quarterly Journal*, Geological Society, vol. 18, pl. 13, f. 17.

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